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ALGAE #64

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ALGAE

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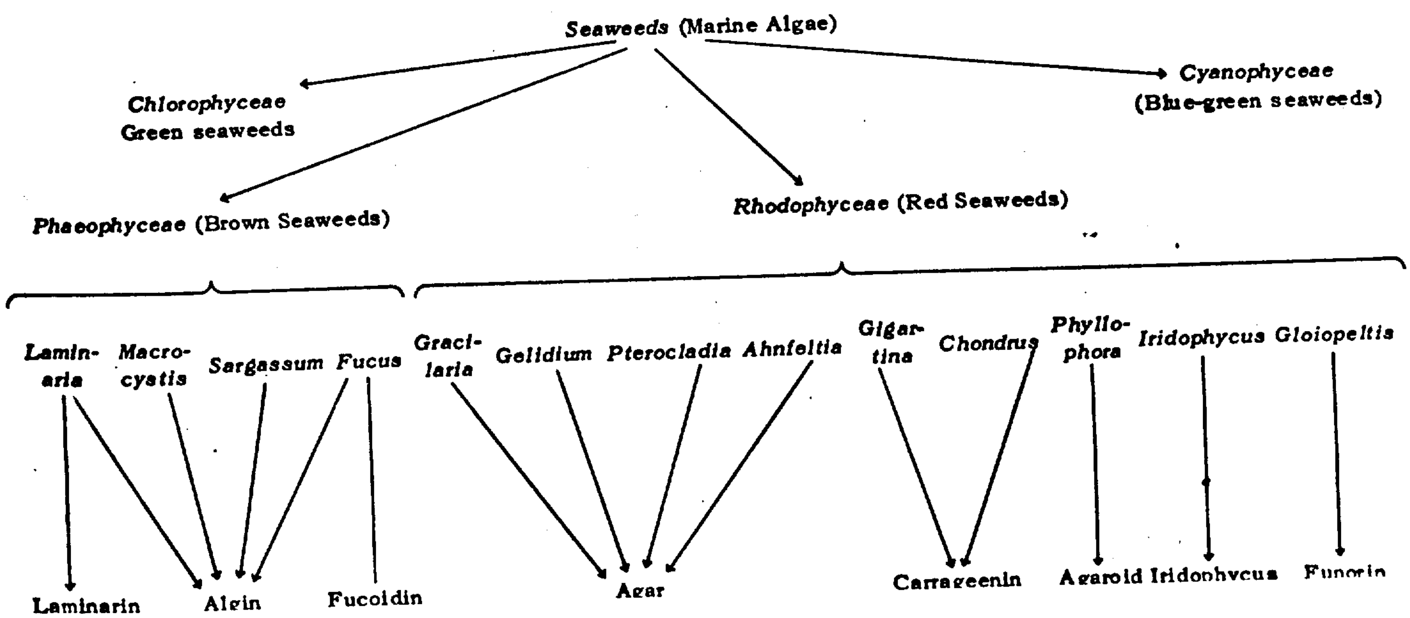
ALGAE

Summary

Algae is widely distributed throughout the costal areas of the world. The peoples of these areas have long used algae as a source of food both for themselves and for their livestock. Despite its wide use, apparently very little information is available on the metabolic and toxicological aspects of algae. Practically all of the studies conducted to date have been concerned with the use of algae in the feeding of livestock.

Table 1 presents the various genera of the Phaeophyceae and Rhodophyceae, as well as the polysaccharide gums derived from them. Monographs have already been prepared on algin, agar, and carrageenin and, rather than reproduce the information here, it is suggested that those monographs be reviewed in conjunction with the current one.

TABLE 1. SOURCE OF SOME SEAWEED POLYSACCHARIDES



Using pigs as experimental animals, Sheehy et al. (156) determined the digestibility coefficient of Laminaria digitata to be approximately 67 and 75 for the organic matter and nitrogen-free extract, respectively. Rhodymenia palmata was found, in tests on rats, to have a net protein utilization value of 42, as compared to 44 for peas and 49 for corn (149). Dulse has been reported to be completely digestible by man (149).

Laminine ((5-amino-5-carboxypentyl) trimethylammonium) monocitrate, extracted from Laminaria angustata, was found by Ozawa et al. (130) to have an LD_{50} of 394 mg/kg when administered i.v. and an LD_{50} of 2.98-3.57 g/kg when injected s.c.

In 1939 Lunde (108) reviewed a number of feeding experiments on poultry, rats, hogs, and horses and concluded that the addition of 5-10% algae meal to fodder showed beneficial results, however, larger amounts must be used with caution because of the iodine and mineral salt content of the algae. A 1953 review by Black (9) indicates that 10-20% Ascophyllum or Laminaria meal may be used in feeds for pigs, sheep, cows, horses and poultry with good results.

MacIntyre (112) reported that the addition to the diet of hens of 10-50% seaweed meal made from Fucus vesiculosus or Ascophyllum nodosum, which was found to be poorly digested by the hens, depressed the digestibility of all dietary nutrients except fat. Studies conducted by Hand and Tyler (59), in which hens were fed seaweed meal made from Laminaria cloustoni, Ascophyllum nodosum or Laminara saccharina, at levels of 10 to 20% for 14 to 16 days indicate that none of the seaweed meals considered produced any positive results of value and that the birds receiving L. cloustoni and A. nodosum tended to lose weight or show a fall in egg production or both.

Tsujimura et al. (182) found that the addition of powdered Laminaria japonica to a flavin-deficient diet produced a better response in rats than the addition of flavin alone, indicating that Laminaria contains other nutritional factors in addition to flavin.

Feeding experimental lots of Corriedal gimmers for 60 days with rations that included 0, 100, 200, or 300 g/day of dried unwashed Macrocystis pyrifera was found by Carrazzoni et al. (20) to produce no adverse effects.

An experiment conducted by Burt et al. (18) revealed no significant differences in the effects upon milk yield from Ayrshire cows among concentrates containing 10% seaweed meal (from Ascophyllum nodosum and Laminaria cloustoni) and 8.75% oatfeed and 1.25% salt. Berry and Turk (5) reported that maintenance of heifers through their second gestation period on a diet in which kelp meal is added at the rate of 4% of the concentrate mixture produced no adverse effects.

BROWN ALGAE

Chemical Information

I. Nomenclature

A. Common Names

1. Brown Algae
2. Phaeophyceae
3. Kelp
4. Brown Seaweed

B. Chemical Name

None

C. Trade Name

None

D. Chemical Abstracts Services Unique Registry Number

977001-75-4

II. Empirical Formula

Not Applicable

III. Structural Formula

The chemical composition of two seaweed meals and the amounts of trace elements contained by them are presented in Tables 1 and 2 (10).

Table 1

Typical Analyses of Seaweed Meals (Dry Basis)

	Laminaria Meals 1	*Laminaria* Meals 2	*Ascophyllum* Meals 1	*Ascophyllum* Meals 2
Total ash	20.10	27.82	21.93	27.50
Crude proteins	7.44	7.57	8.31	9.11
Ether extract	0.51	1.74	3.23	2.31
Crude fibre	5.65	4.04	3.14	4.02
N-free extractives	66.30	58.83	62.84	57.06
Calcium	1.64	2.46	1.22	1.58
Phosphorus	0.17	0.24	0.12	0.15
Chloride	6.53	—	—	5.98
Starch equivalent	—	49	19	—

Table 2

Trace Element Content of Seaweed Meals

(p.p.m. of dry matter)

	Co	Ni	Mo	Fe	Pb	Sn	Zn	V	Ti
Laminaria meal (January sample) ..	.56	2.0	.50	283	10	0.7	117	1.3	19
Ascophyllum meal (January sample) ...	.41	1.5	.69	163	6	1.0	153	1.9	9

	Cr	Ag	Rb	Li	Sr	Ba	Mn	Cu
Laminaria meal (January sample) ...	1.2	0.7	250	6	3,000	60	30	—
Ascophyllum meal (January sample) ...	0.7	0.3	80	4	2,000	50	50	4

The chemical composition of seaweed meals used by Burt et al. in a feeding study with cows is presented in Table 3 (18).

Table 3. Chemical composition of seaweed meals.

(Percentage of dry matter.)

Food	Dry matter (%)	Crude protein	True protein	Ether extract	Fibre	Nitrogen-free extractives	Ash	CaO	P_2O_5	NaCl
Ascophyllum nodosum meal	88·56	6·93	5·69	3·33	5·49	60·82	23·43	2·52	0·262	3·82
Laminaria cloustoni meal	90·83	11·98	8·32	0·66	8·70	52·75	25·91	2·63	0·590	11·91

IV. Molecular Weight

Not Applicable

V. Specifications

Food Chemicals Codex	
Ash (Total)	Not more than 35%
Iodine content	Between 0.15% and 0.22%
Loss on Drying	Not more than 13%
Limits of Impurities	
Arsenic (as As)	Not more than 3 ppm
Heavy metals (as Pb)	Not more than 40 ppm
Lead	Not more than 10 ppm

VI. Description

A. General Characteristics

The dehydrated seaweed obtained from Macrocystis pyrifera and related species is dark green to olive brown in color and has a salty, characteristic taste.

B. Physical Properties

Not Applicable

C. Stability

No Information Available

VII. Analytical Methods

None

VIII. Occurrence

Macrocystis pyrifera is found in the temperate zones of the Pacific Ocean. The commercially harvested beds, however, are found off Southern California.

RED ALGAE

Chemical Information

I. Nomenclature

A. Common Names

1. Red Algae
2. Red Seaweed
3. Rhodophyceae

B. Chemical Name

None

C. Trade Name

None

D. Chemical Abstracts Services Unique Registry Number

977007-74-1

II. Empirical Formula

Not Applicable

III. Structural Formula

Not Applicable

IV. Molecular Weight

Not Applicable

V. Specifications

None

VI. Description

No Information Available

VII. Analytical Methods

None

VIII. Occurrence

Seaweed	Location
Ahnfeltia plicata	Russia (Maritime Coast and White Sea area)
Camphylaephora hypneoides	China
Endocladia muricata	California
Eucheuma spinosum	China
E. isiforme	China
E. denticulatum	China
Gelidium amansii	California, China
G. cartilagineum	California, China, S. Africa
G. corneum	China, California
G. australe	California
G. pristoides	S. Africa
Gigartina asperifolia	California
G. canaliculata	California
G. serrata	California
Gloiopeltis	California
Gracilaria confervoides	China, Australia, S. Africa, California
G. lichenoides	China, Australia
Phyllophora nervosa	Russia, Black Sea
P. rubens	Russia, Black Sea
Pterocladia lucida	Australia
P. capillaceae	Brazil
Suhria vittata	S. Africa
Ahnfeltia plicata	North East Coast
Eucheuma isiforme	Florida
Gracilaria confervoides	East Coast of N. America
G. multipartita	East Coast of N. America

DULSE

Chemical Information

I. Nomenclature

A. Common Names

1. Dulse
2. Rhodymenia Palmata
3. Red Kale
4. Neptune's Girdle
5. Sou-soll
6. Sea-devil
7. Horse Seaweed
8. Cow Seaweed
9. Animal Seaweed

B. Chemical Name

None

C. Trade Name

None

D. Chemical Abstracts Services Unique Registry Number

977007-84-3

II. Empirical Formula

Not Applicable

III. Structural Formula

A complete analysis of Rhodymenia palmata gave the following results (149).

Substance	*Percent*
ash	21.2
total sulfate	0.7
nitrogen	3.5
fats and pigments soluble in carbon tetrachloride	2.4
alcohol solubles	7.9
uronic anhydride	3.3
cellulose	2.4
reducing sugars	36.2 anhydropentose
	3.5 anhydrohexose

IV. Molecular Weight

Not Applicable

V. Specifications

None

VI. Description

A. General Characteristics

The Rhodymenia palmata plant is composed of dull red, forked, irregularly divided, rubber-like blades which originate in a short, inconspicuous stipe. It grows to a height of 5-15 inches and a width of 1-3 inches.

B. Physical Properties

Not Applicable

C. Stability

No Information Available

VII. Analytical Methods

None

VIII. Occurrence

Rhodymenia palmata is widely distributed throughout the world.

Biological Data

I. Acute Toxicity

Substance	Animal	Sex & No.	Route	Dosage (mg/kg Body Wt)	Measurement	Ref.
Lam*	Mice	-	i.v.	394	LD_{50}	130
Lam*	Mice	-	s.c.	2980-3570	LD_{50}	130

*Laminine ((5-amino-5-carboxypentyl) trimethylammonium) monocitrate

Mice

Using mice, Ozawa et al. investigated the acute toxicity of Laminine ((5-amino-5-carboxypentyl) trimethylammonium) monocitrate (Lam), extracted from Laminaria angustata. The LD_{50}'s by the intravenous and subcutaneous routes were determined at 394 mg/kg and 2.98-3.57 g/kg, respectively. Intravenous injection produced spasm and opisthotonus, followed in several minutes by death. A dose of 500 mg/kg i.p. produced no characteristic change other than weak tremor of the hind legs and hypomotility and 200 mg/kg i.p. was found to exhibit no effect (130).

II. Short-term Studies

In 1939 Lunde reviewed a number of feeding experiments on poultry, rats, hogs, and horses in which algae meal was fed at various levels. He concluded that the addition of 5-10% algae meal to fodder showed beneficial results, however larger amounts must be used with caution because of the iodine and mineral salt content of the algae (108).

In 1953, Black reviewed the available literature concerning the use of brown algae as a stock food. The results of feeding trials with pigs, sheep, cows, horses and poultry indicate that 10-20% Ascophyllum or Laminaria meal may be used in feeds with good results. It was found that ruminants can utilize the products better than pigs. The addition of 20% algae meal to the feed of hens upset their mineral metabolism while 10-15% was completely acceptable (9).

Hens

In studies using laying hens, MacIntyre examined the digestibility of dried ground seaweed meal made from Fucus vesiculosus and Ascophyllum nodosum. Groups of six Barred Plymouth Rock laying hens, approximately one year old, were given rations containing 10-50% seaweed meal for periods from 4 to 8 days. The rations and results of the trials are presented in Table 1. The results indicate that the seaweed was poorly digested by the hens, even at 10% of the diet, and that the addition of seaweed meal to the basal ration depressed the digestibility of all nutrients except fat (112).

TABLE 1.—AVERAGE DIGESTIBILITY COEFFICIENTS OF BASAL RATIONS, BASAL RATIONS PLUS SEAWEED MEAL, AND SEAWEED MEALS[1]

Year	Trial number	Ration	Digestibility coefficients of basal rations and basal rations plus seaweed meals: Organic matter	Crude protein	Ether extract	Nitrogen free extract	Crude fibre	Per cent change in digestibility coefficients of basal rations caused by addition of seaweed meals: Organic matter	Crude protein	Ether extract	Nitrogen free extract	Crude fibre	Digestibility coefficients of seaweed meals: Organic matter	Crude protein	Ether extract	Nitrogen free extract	Crude fibre
1952	1	Basal ration	75	82	71	75	15	—	—	—	—	—	—	—	—	—	—
	2	70% Basal + 30% Seaweed Meal	62	72	74	69	6	−17	−12	+ 4	− 8	−60	22	16	37	42	Neg.
1953	3	Basal ration	72	84	82	76	2	—	—	—	—	—	—	—	—	—	—
	4	70% Basal + 30% Ascophyllum	56	62	79	61	Neg.	−24	−25	− 4	−20	—	10	Neg.	75	20	Neg.
	5	70% Basal + 30% Fucus	61	[illegible]	88	65	2	−15	−18	+ 4	−14	—	33	23	90	31	Neg.
	6	50% Basal + 50% Fucus	43	52	73	47	Neg.	−40	−38	−11	−38	—	10	13	64	15	Neg.
1954	7	Basal ration	80	91	83	82	Neg.	—	—	—	—	—	—	—	—	—	—
	8	70% Basal + 30% Ascophyllum	58	64	79	61	Neg.	−27	−30	− 5	−22	—	2	Neg.	55	24	Neg.
	9	90% Basal + 10% Fucus	72	79	82	77	Neg.	−10	−13	− 1	− 6	—	3	Neg.	64	26	Neg.
	10	70% Basal + 30% Fucus	57	57	81	65	Neg.	−29	−37	− 2	−21	—	Neg.	Neg.	72	23	Neg.

[1] Values represent the mean of individual determinations from six birds.

In a study by Hand and Tyler, three different seaweed meals, Laminaria cloustoni, Ascophyllum nodosum and Laminaria saccharina, were fed to groups of four Rhode Island Red pullets at levels of 10 and 20% in a basal ration for periods of 14-16 days. Analysis of the basal ration and of the seaweed meals is presented in Table 2. The results of the study indicate that none of the seaweed meals considered produced any positive results of value, although L. saccharina meal showed no detrimental effects. Birds receiving L. cloustoni or A. nodosum meal tended to lose weight or show a fall in egg production or both as a result of receiving less energy than was contained in the normal ration. The high chloride content of all three seaweed meals caused very heavy water consumption and heavy excretion of water and chloride, but this did not appear to affect the general health of the birds. Changes observed in calcium, phosphorus and nitrogen retentions and balance could be explained on the basis of changes in egg production. The results of a further study in which L. cloustoni (stipe), L. cloustoni (frond) and A. nodosum were fed at levels of 10 and 15% for 100 days support these conclusions (59).

Table II

Average analysis of the dry matter of the basal ration and of the three seaweed meals

	Basal ration %	*Laminaria cloustoni* %	*Ascophyllum nodosum* %	*Laminaria saccharina* %
Crude protein	18·59	14·12	10·25	4·15
Ether extract	3·62	1·30	1·90	0·31
Crude fibre	8·48	5·40	3·50	4·80
Nitrogen free extract	64·16	37·90	60·85	72·54
Total ash	5·15	41·28	23·50	18·20
Insoluble ash	0·53	0·54	0·32	0·21
Calcium	0·50	1·21	1·26	1·48
Phosphorus	0·94	0·36	0·12	0·13
Chloride	0·15	13·82	5·56	5·95
Moisture	13·41	7·20	10·80	8·18

Rats

For a period of approximately 30 days, Tsujimura et al. maintained 16 rats on a flavin-deficient diet. The rats, which at this time exhibited a marked flavin deficiency manifested in rough fur and poor weight gain, were divided into 3 groups: the first continued to receive the flavin-deficient diet, the second received 5 micrograms of flavin phosphate per day in addition to the flavin-deficient diet, and the third received 1 g of powdered Laminaria japonica per day in addition to the flavin-deficient diet. The animals continued on the flavin-deficient diet continued to show poor growth, roughening of the fur, and some finally died. However, the flavin-treated and algae-treated groups both showed normal growth and smooth fur. Furthermore, the Laminaria-group responded better than the flavin-group, indicating that Laminaria contains other nutritional factors in addition to flavin (182).

Sheep

For a period of 60 days, Carrazzoni et al. fed 4 groups of 3 Corriedale gimmers each with rations that included 0, 100, 200 or 300 g of dried, ground, unwashed Macrocytis pyrifera per day. The control lambs were given 20 g of bone flour per day to provide minerals. All of the animals grew well and no toxic effects were observed. No variations were found in the blood levels of calcium, magnesium, phosphorus, urea, and total protein, nor in the number of red corpuscles or the hemoglobin values. Ruminal pH and abdominal circumference were unaffected and no digestive disturbances were observed. Mating of the lambs resulted in normal conception, gestation and parturition in all cases (20).

Cows

An experiment conducted by Burt et al. showed no significant differences in the effects upon milk yield from Ayrshire cows among those receiving concentrates containing 10% of seaweed meals (from Ascophyllum nodosum and Laminaria cloustoni) and those receiving 8.75% oatfeed and 1.25% salt. The milk produced on the oatfeed-salt mixture had a slightly but significantly higher solids-not-fat content than that on the mixtures containing seaweed meals. It was pointed out that the oatfeed mixture had a starch equivalent of only 39, which is a low value for an ingredient of concentrate mixtures for dairy cows. The chemical composition of the seaweed meals and oatfeed is presented in Table 1 (18).

Table 1. *Chemical composition of the seaweed meals and oatfeed*

(Percentage of dry matter.)

Food	Dry matter (%)	Crude protein	True protein	Ether extract	Fibre	Nitrogen-free extractives	Ash	CaO	P_2O_5	NaCl
Ascophyllum nodosum meal	88·56	6·93	5·69	3·33	5·49	60·82	23·43	2·52	0·262	3·82
Laminaria cloustoni meal	90·83	11·98	8·32	0·66	8·70	52·75	25·91	2·63	0·590	11·91
Oatfeed	91·00	8·48	7·81	4·79	16·59	67·33	2·81	0·13	0·729	0·20

Using 74 heifers of approximately one year of age, Berry and Turk conducted a feeding experiment to investigate the value of kelp meal in rations for dairy cattle. The animals received corn silage and clover hay in amounts that would be readily consumed each day, plus 4 pounds of a concentrate mixture containing approximately 14% total protein. Half of the animals were given kelp meal at the rate of 4% of the concentrate mixture. Maintainence of all of the animals on this regimen through completion of their first gestation period and of 52 of the animals through completion of their second gestation period revealed no significant effects resultant from the feeding of kelp meal (5).

III. Long-term Studies

Man

In the Far East seaweeds have for centuries been an accepted food for humans, constituting up to 25% of their diet. It is stated that people in these countries derive considerable nourishment from seaweeds by virtue of the fact that they have been fed on them since childhood and the intestinal microflora essential for the metabolism of certain of the seaweed constituents has therefore been set up (10).

IV. Special Studies

None

Biochemical Aspects

I. Breakdown

No Information Available

II. Absorption - Distribution

Using pigs as experimental animals, Sheehy et al. determined the digestibility coefficient of Laminaria digitata meal to be approximately 67 and 75 for the organic matter and nitrogen-free extract, respectively (156).

The crude protein in dulse can be readily utilized by either man or animals. In tests on rats, Rhodymenia palmata was found to have a net protein utilization value of 42, as compared to 44 for peas and 49 for corn. It has been reported that dulse is completely digestible by man (149).

III. Metabolism and Excretion

No Information Available

IV. Effects on Enzymes and Other Biochemical Parameters

Sumita et al. reported that the feeding of kelp meal (5-10 g/day) to White Leghorn hens increased the iodine content of the eggs produced (168).

The iodine content of dried samples of Laminaria japonica ranges from 0.17 to 0.55%. It has been reported that 98-99% of this iodine is absorbed from the gastro-intestinal tract when ingested. Ino et al. conducted a study to determine the effect of seaweed ingestion on the thyroidal uptake of radioiodine. The oral administration of 7-16 g of L. japonica per day (0.02-0.05 g I/day) for 1-14 days resulted in a marked decrease in the uptake of radioiodine by normal and Grave's disease persons. Discontinuation of ingestion of seaweed resulted in the return to normal of the value for radioiodine uptake in about 2 weeks (73).

V. Drug Interaction

No Information Available

VI. Consumer Exposure Information

No Information Available

ALGAE

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P32. **The Value of Kelp Meal in Rations for Dairy Cattle.*** M. H. Berry and K. L. Turk,† University of Maryland.

The value of adding kelp meal to dairy rations has been investigated with 74 dairy heifers. Heifers were placed on experiment at approximately one year of age and were continued through their first calving period. Fifty-two animals were kept on the experiment through a second gestation.

When placed on the experiment, the heifers were paired according to breed, age and size and were fed in dry lot. They received corn silage and U. S. No. 2 clover hay in amounts that would be readily consumed each day, plus 4 pounds of a concentrate mixture containing approximately 14 per cent total protein. Kelp meal was fed at the rate of 4 per cent of the concentrate mixture to one animal of each pair.

Results from the 37 pairs of heifers completing their first gestation period showed no advantage in favor of either ration. Heifers in the control group made an average daily gain of 1.05 pounds and those in the kelp

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group gained 1.03 pounds per day. In the control group, 1.45 services per conception were required, while 1.86 services per conception were required by the heifers receiving kelp. There were 2 abortions in each group, 5 cases of retained placentas in the control group and 2 cases in the kelp group, and 2 animals from each group were discarded as non-breeders. Heifers on the control ration had an average gestation of 276.5 days and those on kelp 275.9 days. Calves born to the kelp fed animals averaged 2.26 pounds heavier at birth than those from animals on the control ration. No significant differences were noted in physical condition of the animals at freshening or in the condition of the calves at birth.

For the 26 pairs of heifers which were continued through a second gestation period, the controls averaged 2.23 services per conception, while the kelp-fed animals averaged 1.92 services. There were 3 abortions and 2 cases of retained placentas in the control group, and 2 abortions and 4 cases of retained placentas in the kelp group. Calves born in the control group averaged 1.71 pounds heavier at birth. The length of gestation averaged 277.7 days for the controls and 275.4 days for the kelp-fed animals. No differences were noted in the physical condition of cows at calving or in the calves born to cows from either ration.

Lactation data showed no differences which could be attributed to the ration. On a 4 per cent fat-corrected-milk basis, the control cows averaged 8089.5 pounds of milk and the kelp cows averaged 7715.2 pounds. In both cases lactations averaged 303 days in length and the average age of the animals at freshening was 2.5 years. Feed consumption records showed no stimulating effect from the feeding of kelp and liveweight changes were slightly in favor of the kelp-fed animals during lactation.

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SEAWEED AS A STOCKFOOD

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The brown seaweed commonly found around the coasts of Britain is a rich source of carbohydrates, minerals, trace elements, vitamins and other growth-promoting substances, and, on the evidence of trials so far reported, it can provide a useful supplementary food for cattle, sheep, pigs and poultry.

ALTHOUGH sheep and cattle have grazed on our shores from time immemorial—in some cases existing almost entirely on seaweeds—and dehydrated seaweeds have long been used in many countries as a stockfood, comparatively little information has hitherto been available on the actual food value of seaweeds. This is due to the fact that very few controlled digestibility trials have been carried out and, where they have, the seaweed used has been mainly cast weed of doubtful origin, giving, in many cases, results of a contradictory nature.

In general, the seaweeds can be divided into four main groups : (1) the brown seaweeds ; (2) the red seaweeds ; (3) the green seaweeds ; and (4) the blue-green seaweeds. But as only the brown seaweeds occur around the shores of Britain in sufficient quantity to make their collection an economic proposition, work has, up to the present been confined entirely to this variety.

Great Variation in Composition In carrying out digestibility trials with seaweed, one of the main difficulties is the great variation in composition. This, however, is also a marked feature of farm foods, especially grassland products. The changes are typical of all plants and, just as in the case of grasses where the composition is closely related to the ratio of leaf to stem, in seaweeds the composition depends on the ratio of frond (leaf) to stipe (stalk).

The brown seaweeds can be further divided into two main classes : (1) the littoral or rock weeds which occur between high and low water mark, with *Ascophyllum nodosum* (knotted wrack) the predominant species; and (2) the sublittoral weeds which grow below low water down to 12 fathoms (72 feet), with *Laminaria cloustoni* predominating. In brief, therefore, two main types of seaweed meal—"*Ascophyllum* meal" and "*Laminaria* meal" can be considered, although only the former is at present available commercially. A typical analysis of these two meals is given in the following table :

	Dry Matter	Crude Protein	True Protein	Ether Extract	Crude Fibre	Total Ash	Nitrogen-free Extractives	Calcium	Phosphorus	Calc. Starch Equiv.
Ascophyllum meal	95.10	8.38	6.31	3.12	2.99	20.86	59.75	1.16	0.114	[illegible]
Laminaria meal	96.04	7.27	5.80	1.67	3.38	26.73	56.49	2.36	0.226	[illegible]

Carbohydrates. In the absence of free sugars, seaweeds contain the [illegible]hydric alcohol mannitol, which varies from 5 per cent to as much as [illegible] cent of the dry matter. D-Mannitol, or manna sugar, is a colour[illegible] odourless, crystalline powder with half the sweetness of sucrose. [illegible] amounts of mannitol are readily utilized, being partly converted to glyc[illegible] but in comparatively large doses it has a mild laxative effect.

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place of the starch of the land plants, a glucose polymer called "laminarin" is present in the brown seaweeds, and in autumn it makes up 25 per cent of the dry matter of the plant. It is easily split up by enzymes and weak acid to give an equal amount of the sugar glucose, and work at the Hannah Dairy Research Institute has shown that it is the only constituent readily utilized by the bacteria in the bovine rumen.

Seaweeds have a low crude fibre content (2–10 per cent), the place of cellulose in the cell wall structure being largely taken by alginic acid (15–25 per cent of the dry matter). Nelson and Lemon (1) have investigated this substance and have concluded that it has considerable nutritive value. The nutritive value of the other carbohydrates present has not yet been investigated.

Proteins. The proteins of seaweeds, in common with those of most other land plants, are less assimilable than animal proteins. Recent work has shown the presence of all the essential amino-acids, but the crude protein content rarely exceeds 15 per cent (5–15 per cent on the dry basis) and seaweeds cannot therefore be regarded as a source of proteins.

Fats. The brown seaweeds contain amounts of fats varying from less than 1 per cent to 8 or 9 per cent, and here also there seems to be very little difference between those present in seaweeds and those in land plants.

Minerals and Trace Elements. A characteristic feature of seaweeds is their high mineral content (up to 35 per cent of the dry matter), and it can be said that they contain all the elements which have so far been shown to play an important part in the physiological processes of the animal. In a well-balanced diet, therefore, seaweed would seem to be an excellent mineral supplement.

The occurrence of iodine is also a point of major importance. Depending on the species and season of the year, the brown seaweeds contain 0.03–[illegible] per cent iodine (dry basis) in a form more valuable than in iodine salts, being partly present as the precursor of thyroxine.

Vitamins. Seaweeds can be considered a valuable source of vitamins. Although they do not contain vitamin A, they do possess its precursor, carotene, and fucoxanthin, a pigment which may also give rise to vitamin A. They also contain vitamins B_1 (thiamine) and B_2 (riboflavin), while recent work by Ericson ([illegible]) has shown the presence of vitamin B_{12} in amounts comparable to those in liver. Vitamin C occurs in appreciable quantities and there is evidence of the presence of vitamins D and E. In addition to these vitamins, seaweeds contain other growth-promoting substances.

Early Digestibility Trials The earliest recorded trials took place in France(3) during the First World War, when the possibility of utilizing seaweed as a supplementary feed for poultry, pigs and horses was investigated. The animals accepted, digested and assimilated the seaweeds, but the interesting point was that the seaweed appeared to remain completely undigested for the first few days. After the sixth day no seaweed [illegible] appeared in the faeces, and the digestibility was excellent.

More recent work in Norway (in [illegible]–40) emphasized the differences that can arise in the nutritive value of seaweed meals according to the [illegible] used and the time of year when it is collected. Lunde (4) conducted [illegible] trials with rats, pigs, [illegible] and poultry, and showed that the addition [illegible] per cent seaweed was very beneficial. [illegible] (5) carried out similar [illegible] with pigs and sheep and tested two proprietary meals, one made from [illegible]littoral weed and the other from the rock weed "knotted wrack".

The results showed that the nutritive value was exceedingly low, especially [illegible] ruminants could utilize it better. The value of the first [illegible] was considered higher than that of the second.

Other trials worthy of mention are those carried out in Eire. In 1943, [illegible] and co-workers [illegible] carried out digestibility trials with pigs, and showed [illegible] had a feeding value for pigs about two and a half times [illegible] intermediate between hay and oats. In addition, by [illegible] mechanical action on the alimentary tube of the [illegible] enhanced the nutritive value of the original basic ration.

[illegible] also been carried out at the Albert Agricultural College [illegible] of three years to determine the nutritive value of [illegible] sheep (20 per cent of the total ration). The most [illegible] collected in the autumn was comparable in feeding value [illegible].

[illegible] In 1940, Tribe (then at the Rowett Research Institute) made a study of the habits of the [illegible] sheep [illegible], which live [illegible] seaweed for the greater part of the year, and collected [illegible] which they selected. These samples were identified [illegible] the Institute. It would appear that the sheep chose the [illegible] laminarin and iodine content and that there [illegible] correlation between palatability and nutritive value. On the [illegible] seemed to select the new growth, the most succulent [illegible], and red weeds such as dulse.

In [illegible] occasionally stored in pit silos or dried and stored [illegible] hay for winter feeding. Work in progress at the Institute has shown [illegible] a much more vigorous acid fermentation than grass and can be preserved by ensiling with very little change in chemical composition.

Digestibility trials (unpublished work) with pigs and sheep were carried out at the Rowett Research Institute in 1947. Four samples of dried, milled seaweed were used to form 20–24 per cent of the total ration, and the samples were purposely chosen to give a wide range in chemical composition. The results confirmed those of previous investigators in that the *Laminaria* meal was more digestible than *Ascophyllum* (knotted wrack), and that ruminants make better use of seaweed than do pigs. In general, *Ascophyllum* meal had not a high digestibility, the protein not being digested itself and even reducing the digestibility of the protein in the basic ration. With pigs, however, the October sample of the *Laminaria* meal had a high digestibility (88 per cent) for carbohydrates but a negative digestibility for protein, while the January sample [illegible] 5 per cent digestibility for carbohydrates and a positive protein digestibility.

In 1952 [illegible] comparison feeding trial with pigs was carried out at the Edinburgh and East of Scotland College of Agriculture, where two sets of [illegible] pigs drawn from two litters were paired off for equality in sex and body weight [illegible] and each pair was divided between two groups. Group [illegible] was [illegible]. The control group received an all-meal mixture and the [illegible] pigs a meal mixture containing seaweed meal. The seaweed meal (*Ascophyllum nodosum*—knotted wrack) [illegible] meal on a pound-for-pound [illegible] 5 per cent [illegible] the quantity [illegible] increased gradually to 12 per cent, at which it [illegible] fed up to bacon weight. The results were encouraging, and [illegible] liveweight gains were recorded with pigs between 50 and 200 lb. live weight; the resulting carcasses were of bacon quality and had no taint.

The feeding of seaweed meal to dairy cows has also been investigated at a number of [illegible] in the [illegible] Scotland(9). In general, it would appear from the [illegible] of the farmers that seaweed meal is rather unpalatable to cows, [illegible] one or two of the farms the cows ate the seaweed meal [illegible] meals were fed at the rate of 8 oz. [illegible] the seaweed was accepted there was a positive [illegible] of the milk. This is being investigated further.

It is [illegible] constituents of feeding stuffs [illegible] there is also an abundance of [illegible] have been carried out [illegible] the [illegible] to determine to what extent protein synthesis [illegible] contents [illegible] a variety of different substances, [illegible] constituents, are made available. The test, [illegible] types of substances the rumen bacteria can [illegible] non-protein nitrogen is available. Laminarin [illegible] a decrease in non-protein nitrogen [illegible] maltose, [illegible] constituent of the brown algae readily utilized by the rumen [illegible].

Feeding [illegible] have been carried out at Reading [illegible] find the level at which seaweed can be fed to hens without upsetting the mineral metabolism. The seaweed meals, two of [illegible] with high and low ash contents, and one *Ascophyllum*, were [illegible] birds used were Rhode Island Red [illegible] approximately one year old and in full production. Summarizing the results it can be said that the replacement of 10 per cent of the basal ration by an equal weight of any of the three seaweed meals had no ill-effect on the [illegible] egg production was [illegible] the birds remained perfectly healthy. Water consumption [illegible] and there was a marked increase in the chloride content of the [illegible] was found, however, that 20 per cent of seaweed meal, when [illegible] in conjunction with a mineral supplement, upset the metabolism of the [illegible] (16 days) were followed by a 200-day [illegible] Rhode Island pullets. For the first 100 days, [illegible] ration was replaced by a similar amount of seaweed [illegible] increased to 15 per cent for the second 100 days. The [illegible] those of the early metabolism experiments, i.e., that [illegible] per cent [illegible] meal could be fed without upsetting the [illegible]

Initial experiments [illegible] been carried out at the Edinburgh and [illegible] Seaweed meal (*Ascophyllum*) has been [illegible] source of vitamins A and D. The [illegible] experiments are now in progress at a [illegible]

In all the [illegible] seaweed definitely increased the palatability [illegible] of the [illegible].

Conclusion [illegible] the evidence available that [illegible] besides [illegible] trace elements, vitamins [illegible] a most beneficial influence [illegible] present in seaweed prov[illegible] excellent roughage, stimulating the movements of the intestine[illegible]

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[illegible] AND PRICES

[illegible] AGRICULTURAL PRODUCTS

[illegible] (NOT ADJUSTED FOR SEASONAL VARIATION)

[illegible]

	Unit	[illegible]	1953 Jan.	1953 Feb.	1953 Mar.	1952 Jan.	1952 Feb.	1952 Mar.
All [illegible]	—	—	312*	303*	286*	307	293	278
[illegible]	—	—	263	276	277	281	278	278
[illegible]	—	—	[illegible]*	313*	291*	315	[illegible]	278
		s. d.						
Wheat	cwt.	31 8	[illegible]	[illegible]	305	285	255	269
[illegible]	„	31 [illegible]	[illegible]	[illegible]	283	[illegible]	363	328
Oats	„	25 3	[illegible]	283	[illegible]	319	307	303
Potatoes	ton	[illegible] 6	[illegible]	215	[illegible]	225	235	218
Hay	[illegible]	—	[illegible]	208	[illegible]	[illegible]	[illegible]	236
Fat cattle	live cwt.	[illegible] 3	[illegible]	272	281	244	255	261
[illegible]	„	73 7	[illegible]	[illegible]	[illegible]	199	210	215
[illegible]	[illegible]	2 [illegible]	[illegible]	259	[illegible]	[illegible]	[illegible]	269
[illegible]	„	1 [illegible]	[illegible]	[illegible]	267	218	258	270
[illegible]	[illegible]	35 [illegible]	[illegible]	[illegible]	364*	[illegible]	[illegible]	350
[illegible]	[illegible]	[illegible] 6	[illegible]	[illegible]	299	293	[illegible]	298
[illegible]	[illegible]	27 5	[illegible]	[illegible]	238	238	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	319*	359	337	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	171	[illegible]	[illegible]	143
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	272
[illegible]	[illegible]	41 [illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	197
[illegible]	[illegible]	[illegible] 6	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	197
[illegible]	„	[illegible] 0	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	242
[illegible]	„	7 [illegible] 9	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	275
[illegible]	„	[illegible] 9	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

* [illegible]

SEAWEED IN ANIMAL FOODSTUFFS

I. AVAILABILITY AND COMPOSITION

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In the June 1953 issue of *Agriculture** the use of seaweed as a stockfood was considered by Dr. Black. The considerable interest which it aroused has prompted this up-to-date review of the common brown seaweeds.

THE value of seaweeds in foodstuffs still affords a good deal of speculation. From time to time digestibility and feeding trials with animals have been carried out in several countries, but the results have not always been in accord. Unfortunately in most cases, and particularly in the digestibility trials, the experiments have been of short duration (12 days). However, in the Far East seaweeds have for centuries been an accepted food for humans, constituting up to 25 per cent of their diet. It is stated that people in these countries derive considerable nourishment from seaweeds by virtue of the fact that they have been fed on them since childhood, and the intestinal microflora essential for the metabolism of certain of the seaweed constituents has thereby been set up. In view of this, feeding and digestibility trials with animals should be carried out for a reasonable period, for, if the correct microflora can be introduced, the whole aspect of seaweed as a food might be changed.

Since seaweeds—and particularly the brown weeds—are high in mineral matter (sulphates and chlorides) and contain certain organic constituents which have been shown to have a laxative effect, as well as constituents which are not readily utilized, there is a limit to the extent to which seaweed can be incorporated in the animal diet. This has been borne out by feeding trials, and thus it can only be regarded as a supplementary foodstuff. When fed up to 10 per cent of the basal diet, however, its value is difficult to assess, since it will depend on the diet with which it is fed. Nevertheless, in view of its unique composition, final assessment of its value in foodstuffs should not be based entirely on nutrition figures. Effect on the general health of the animal, productivity, etc., although now well recognized by the many users of seaweed, are, however, difficult to prove scientifically.

Possible Commercial Exploitation Although a great variety of seaweeds occur around the 5,300 miles of Scottish coastline, only a limited number are present in sufficient quantity to justify their commercial exploitation. Between high and low water mark at least a quarter of a million tons of littoral brown seaweed, mainly *Ascophyllum nodosum* (knotted wrack), occur, while from low water down to 10 fathoms (60 feet) an area of 2 million acres supports about 10 million tons of sublittoral weed (*Laminaria* or "tangle"), of which 3-4 million tons are concentrated in quantities of economic value. Two main types of seaweed meal—*Ascophyllum* and *Laminaria* meal—could therefore be available in quantity and, allowing for regeneration, over a million tons could be harvested per year in Scotland alone, giving about a quarter of a million tons of dry material. This quantity may be insignificant when compared with land crops, but it could still make a valuable contribution to our home-produced feedingstuffs.

* Seaweed as a Stockfood, pp. 126-30.

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In common with any plant material, the brown seaweeds, and particularly the *Laminaria*, undergo a marked seasonal variation in chemical composition. In the spring of the year, before marked photosynthesis begins, the dry matter is at a minimum and is composed mainly of minerals, alginate and protein. As growth proceeds, there is a marked increase in the carbohydrate content, with a corresponding decrease in protein and mineral matter. With the *Laminaria*, the dry matter content increases from 10 per cent in the spring to 25 per cent in late summer, and the latter period would appear to be the best time to harvest from a carbohydrate point of view. With *Ascophyllum*, however, the seasonal variation is less marked (which has no parallel in any land crop) and harvesting can be carried out at any time of the year.

Like land plants, seaweeds are composed mainly of carbohydrates, fats, proteins and mineral matter, but they are also rich sources of vitamins and many growth-promoting factors. Seaweeds have the advantage over land crops in that they grow in an ideal environment, in which the nutrients in sea water are being constantly renewed by nature, whereas on the land modern methods of intensive cultivation lead to complete exhaustion of the soil, unless, with a knowledge of the nutritional and other growth requirements of the crops, the deficiencies are replaced by man. Seaweeds, therefore, contain all the elements found in sea water, as well as a rich bacterial microflora which contributes to their composition.

Table 1

Typical Analyses of Seaweed Meals (Dry Basis)

	Laminaria Meals		*Ascophyllum* Meals	
	1	2	1	2
Total ash	20.10	27.82	21.93	27.50
Crude proteins	7.44	7.57	8.31	9.11
Ether extract	0.51	1.74	3.28	2.31
Crude fibre	5.65	4.04	3.14	4.02
N-free extractives	66.30	58.83	62.84	57.06
Calcium	1.54	2.46	1.22	1.58
Phosphorus	0.17	0.24	0.12	0.15
Chloride	6.58	—	—	5.98
Starch equivalent	—	49	19	—

Carbohydrates, Proteins and Fats The main carbohydrates found in the brown seaweeds are mannitol, laminarin, fucoidin, alginic acid, and cellulose. The sweet-tasting mannitol takes the place of the sugars of the land plants. In small amounts it is readily utilized and may be partly converted to glycogen, but in larger doses it can have a pronounced laxative effect. It varies from 5 to 25 per cent of the dry matter, depending on the time of harvesting. In place of the starch of land plants the brown seaweeds contain laminarin, which is absent from the *Laminaria* in the spring but which can make up over 25 per cent of the dry matter in the autumn. It behaves towards acids in much the same way as starch, and is as readily utilized as maltose by the bacteria in the bovine rumen. Its presence, therefore, would considerably add to the value of seaweed. No metabolic studies have been carried out with fucoidin, but it is unlikely to be utilized, and feeding experiments have shown that it exerts a laxative effect. Alginic acid, the main cell-wall constituent of the brown seaweeds and bearing some relation to vegetable pectin, has, in some animal experiments, been shown to be utilized, and in others to have a very low digestibility. It is thought to form a complex with proteins, which may explain the negative protein digestibility values obtained in some digestibility trials.

[illegible] content of the brown seaweeds is low compared with land [illegible] of the dry matter), but roughage in a diet containing [illegible] provided by fucoidin and alginic acid—carbohydrates [illegible] utilized but which are capable of absorbing con[illegible] water.

There is [illegible] yet of the general type of proteins present in sea[illegible] have been isolated have been shown to contain [illegible] acids ([illegible]). The crude protein content rarely exceeds [illegible] and decreases to as low as 5 per cent in the late [illegible] the brown seaweeds cannot be regarded as a source [illegible] such as *Rhodymenia palmata* (dulse), however, [illegible] crude proteins of high biological value.

[illegible] contain varying amounts of fats—from 1 per cent in [illegible] per cent in the most exposed weed, *Pelvetia canalicu-*[illegible].

[illegible] Vitamins. The brown seaweeds contain all the elements present in sea water [illegible] some of them to several thousand times their concen[illegible] water ([illegible]). They therefore contain all the elements [illegible] an important part in the physiological processes of the an[illegible] is a comparatively new science and a great deal [illegible] regarding all the elements necessary for health. S[illegible] however, to demonstrate that several of th[illegible] result from trace element deficiencies, and [illegible] is obviously a wise precaution to include in [illegible] seaweed. Although seaweeds cannot be [illegible] mineral supplement, since they are too low in [illegible] these differences can be easily and cheaply adjusted. [illegible] source of iodine. This is present partly in the [illegible] amino-acids, which have been recommended for [illegible] production of dairy cows, for egg produc[illegible] spermatogenesis in bulls and rams.

Table 2

[illegible] Element Content of [illegible]weed [illegible]

(p.p.m. of dry matter)

	Co	Ni	Mo	Fe	Pb	Sn	Zn	V	Ti
[illegible] ...	.56	2.0	.50	235	10	0.7	117	1.3	19
[illegible] ...	.41	1.5	.60	163	6	1.0	102	1.9	9

	Cr	Ag	Rb	Li	Sr	Ba	Mn	Cu
[illegible] ...	1.2	0.7	250	6	3,000	60	30	—
[illegible] ...	0.7	0.3	[illegible]	4	2,000	[illegible]	50	4

[illegible] seaweeds are unique, for not only do they contain the vitamins [illegible] land plants, but also vitamins like B_{12}, which [illegible] their [illegible] to attached bacteria. Vitamin A [illegible] ([illegible]), but [illegible] seaweeds contain its precursor, [illegible] as well as the brown pigment fucoxanthin, which may [illegible] precursor of this vitamin. In the B group they contain the vitamins B_1 (thiamine) ([illegible]), B_2 (riboflavin) ([illegible]), and B_{12} ([illegible]) in varying amounts, and it is noteworthy that several of the [illegible] seaweeds contain 0.5-1.0 μg. B_{12}/g. dry weight, which is as high as that found [illegible] most known sources of this vitamin. Vitamin C (ascorbic [illegible] in lucerne (up to 3,000 p.p.m.) ([8]). This [illegible] but recent work has shown that it can be [illegible] by the addition of sodium alginate, which is one of the constituents of the brown seaweeds. Doubt still exists as to the occurrence of vitamin D_2 in plants, but [illegible] have now shown that seaweeds do have a distinct antirachitic [illegible] ([9] and [10]) and, for example, with chickens it can be fed as the sole source of this vitamin up to the age of 16 weeks.

Since the discovery of tocopherol (vitamin E, anti-sterility vitamin) in soya bean oil, there has been little evidence of its occurrence in other plants. Recent work, however, has [illegible] present in the brown seaweeds in amounts varying from [illegible] dry matter, being highest in the most [illegible] wrack) ([11]). This vitamin has been reported [illegible] barrenness in sows, while [illegible] The presence of the vitamins [illegible] has also been reported ([12]). In addition to the [illegible] other growth-promoting substances [illegible] now in progress indicates the presence of antibiotics.

A Useful Supplement. The chemical composition, as given in Tables 1 and [illegible] shows that the brown seaweeds, and particularly the *Laminaria*, could, if [illegible] at a certain time of the year, be regarded as a source of [illegible] some nutritive value, but not as a source of proteins. [illegible] seaweed can be safely introduced into the animal's [illegible] its metabolism. At this level, [illegible] seaweeds contribute bulk, major elements, [illegible] vitamins, antibiotics and growth-promoting substances.

Next month: Feeding and [illegible] Trials.

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556. THE USE OF SEAWEED MEALS IN CONCENTRATE MIXTURES FOR DAIRY COWS

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There has recently been some interest in the possibility of increasing the utilization of seaweed for livestock feeding. Only the brown seaweeds occur in sufficient quantity to justify their collection for this purpose. Quantitative surveys of the main deposits around the Scottish coasts(1) showed deposits of over 180,000 tons of the littoral (mainly *Ascophyllum nodosum*) and about 10,000,000 tons of the sublittoral (mainly *Laminaria cloustoni*) brown seaweeds.

Black(2) and Woodward(1) reviewed various experiments on the use, chiefly in the rations of sheep, pigs and poultry, of seaweed meals for stock food, and concluded that ruminants make better use of seaweed meals than do pigs. Senior, Collins & Kelly(3) in digestibility trials with sheep, found that their best seaweed sample, *Laminaria* collected in the autumn, had a feeding value comparable to that of meadow hay. The same workers observed that the protein in these materials generally had a low and sometimes a negative digestibility. This was confirmed in experiments at the Rowett Research Institute (unpublished; quoted by Black(2) and Woodward(1)), and *Laminaria* meal was found to be more digestible than *Ascophyllum*.

Very little critical work has been done on the value of seaweed meals for dairy cows, although these materials are being used commercially. Dunlop(4), using cows on seventeen farms, studied the effect of substituting approximately 200 g. of *Ascophyllum* meal daily for a similar amount of the normal concentrate ration, and concluded that there were considerable increases in butterfat production.

In view of the lack of information, obtained under carefully controlled conditions, about the value of seaweed meals to dairy cows, it was decided to compare samples of the two main types of seaweed meal with a feed of known nutritive and commercial value. An experiment has therefore been carried out to compare the effects on the yield and composition of milk, of concentrate mixtures containing (*a*) *A. nodosum* meal, (*b*) *Laminaria cloustoni* meal, (*c*) oatfeed and common salt. Black(2) and Dunlop(5) indicated that seaweed meals were relatively unpalatable when fed to dairy cows, and this was confirmed in preliminary small-scale trials in the Institute herd. It was evident that not more than about 10% of seaweed meal could be used, and that this would have to form part of a concentrate mixture containing ingredients of high palatability.

MATERIAL AND METHODS

The *Ascophyllum nodosum* used was collected in the spring of 1953 and the *Laminaria cloustoni* in the autumn of 1952: both were dried and milled to produce suitable meals. The oatfeed used was the by-product of the production of oatmeal and had a calculated starch equivalent of 45.

Analyses of the two seaweed meals and the oatfeed are given in Table 1. The composition of the former agrees with data quoted by Black (2), after making due allowance for the considerable variation which occurs naturally in these materials. The oatfeed differed from the seaweed mainly in having a higher percentage of fibre and soluble carbohydrate, and a lower ash content.

Table 1. *Chemical composition of the seaweed meals and oatfeed*

(Percentage of dry matter.)

Food	Dry matter (%)	Crude protein	True protein	Ether extract	Fibre	Nitrogen-free extractives	Ash	CaO	P_2O_5	NaCl
Ascophyllum nodosum meal	88·56	6·93	5·69	3·33	5·49	60·82	23·43	2·52	0·262	3·82
Laminaria cloustoni meal	90·83	11·98	8·32	0·66	8·70	52·75	25·91	2·63	0·590	11·91
Oatfeed	91·00	8·48	7·81	4·79	16·59	67·33	2·81	0·13	0·729	0·20

Three concentrate mixtures, designated A, B and C, containing *Ascophyllum nodosum* meal, *Laminaria cloustoni* meal and oatfeed respectively were prepared and cubed. The constituents of these mixtures and their relative proportions are shown in Table 2. In the control mixture C, $8\frac{3}{4}$% of oatfeed and $1\frac{1}{4}$% common salt were used, in contrast to 10% of seaweed meal in the other mixtures, the salt being added in order to make some adjustment for the much lower salt content, and higher soluble carbohydrate content of the oatfeed. The chemical composition of the three concentrate mixtures in Table 3 shows very little variation between them.

Table 2. *Composition of the concentrate mixtures, A, B and C*

(Percentage by weight.)

Mixture A 10% *Ascophyllum nodosum* meal
Mixture B 10% *Laminaria cloustoni* meal
Mixture C $8\frac{3}{4}$% oatfeed plus $1\frac{1}{4}$% common salt
Each with 90% of the following:

15 barley meal	10 decort. cotton cake
$31\frac{1}{4}$ maize germ meal	15 decort. groundnut cake
5 rice meal	$2\frac{1}{2}$ dicalcium phosphate
5 molasses	$1\frac{1}{4}$ limestone flour
5 linseed cake	

Table 3. *Chemical composition of the foods*

(Percentage of samples as fed.)

Food	Crude protein	True protein	Ether extract	Fibre	Nitrogen-free extractives	Moisture	Ash	CaO	P_2O_5	NaCl
Concentrates:										
Mixture A	17·74	16·71	6·68	4·82	50·22	11·82	8·72	2·22	2·33	0·62
Mixture B	17·88	16·22	6·20	5·22	49·69	12·22	8·79	2·01	2·29	1·26
Mixture C	17·12	16·86	6·75	5·37	50·96	12·38	7·42	1·60	2·20	1·34
Hay*	7·89	7·02	1·56	27·02	36·78	21·36	5·39	—	—	—
Kale*	1·68	1·25	0·31	2·87	9·03	84·7	1·41	—	—	—

* Mean values for three samples.

Eighteen high-yielding Ayrshire cows were used in this experiment, twelve of which were in the first 2 months of lactation, and six in the third and fourth months, when the experiment started.

The layout of the trial was similar to that described by Cochran, Autrey & Cannon (6), and consisted of two complementary 3×3 Latin squares as follows, replicated three times:

	Cow			Cow		
Period	1	2	3	4	5	6
I	A	B	C	A	B	C
II	B	C	A	C	A	B
III	C	A	B	B	C	A

where A, B and C are the three concentrate mixtures.

An initial control period of 2 weeks on normal herd rations was followed by three experimental periods, each of 3 weeks' duration. Owing to the relatively small differences between the concentrate mixtures, the changeover from one type to another was made abruptly.

A basal roughage ration consisting of 30 lb. marrowstem kale and an average of 18 lb. hay, estimated to supply nutrients for maintenance and the production of the first $1\frac{1}{2}$ gal. of milk, was fed daily to each cow throughout. The amount of hay fed to each cow was based on her live weight in the control period as estimated by taking chest girth measurements and using the conversion tables for the Ayrshire breed given by Davis, Morgan, Brody & Ragsdale (7). A difference in estimated live weight of 70 lb. from the standard of 1000 lb. was met by an adjustment of 1 lb. hay/day to the average quantity of 18 lb.

Concentrate cubes A, B, or C were fed at the rate of $3\frac{1}{2}$ lb./gal. of milk above the first $1\frac{1}{2}$ gal. The quantity of concentrates was originally based on the yield of each cow during the control period, and was subsequently adjusted by a reduction of 1 lb./head/day at each changeover.

The cows were fed individually, and all food offered, and refusals were weighed. Milking was twice daily and yields were recorded at each milking. Samples for the determination of the fat and solids-not-fat percentages of the milk were taken at four consecutive milkings in each week, and a single weighted composite sample prepared for each cow for analysis. The foods were analysed by the conventional methods: the fat content of the milk was determined by the Gerber method, and the total solids content gravimetrically.

At the end of the control period and each experimental period, the chest girth of each cow was recorded and its fatness and the handling properties of the skin were estimated subjectively on scales ranging from 0 to 10 points.

RESULTS

The mean milk yield and percentages of fat and solids-not-fat for each treatment, computed from the data for the last week of each experimental period, are shown in Table 4. The solids-not-fat percentages were expressed in terms of the fat-free milk before computation. One cow had a severe attack of mastitis in the last experimental period and her values for this period were calculated using the missing plot technique applied by Blaxter & French (8) to experiments of this type.

The differences between the mean milk yields produced under each treatment were negligible. The lowest mean fat percentage was associated with mixture B and the highest with mixture A. Analysis of variance showed that differences between treatments in

Table 4. *Mean milk yield, fat, and solids-not-fat percentages for each treatment computed from the values for the last week of each feeding period*

Treatment	Mean milk yield (lb./cow/week)	Mean fat (%)	Mean solids-not-fat (%)
Concentrate A	312·6	3·68	8·70
Concentrate B	309·7	3·52	8·65
Concentrate C	309·9	3·60	8·79

milk yield and fat percentage were not statistically significant. The milk yield analysis gave a value for the standard error of a treatment mean weekly yield/cow of ±3·43 lb., or 1·1 % of the general mean. On the basis of this low standard error, if a difference between treatments of 10·5 lb./cow/week had been observed it would have been regarded as statistically significant.

The analysis of variance for solids-not-fat is shown in Table 5. There was a significant group-treatment interaction indicating that the effect of treatment varied from group to group, and a significant variation between treatments. The means and standard error

Table 5. *Analysis of variance of solids-not-fat percentages*

	D.F.	S.S.	M.S.	Significance of F
Total	53	5·3194	—	—
Between groups	5	0·7321	0·1464	**
Cows within groups	12	3·4814	0·2901	**
Periods within groups	12	0·6284	0·0524	**
Treatments	2	0·1544	0·0772	**
Treatment × group	10	0·2547	0·0255	**
Error	12	0·0684	0·0057	—

** Significant at the 0·01 level of probability.

	Treatment means	S.E.M. of 18 cows
A	8·70	±0·0178
B	8·65	
C	8·79	

quoted at the bottom of Table 5 show that the mean solids-not-fat percentage for mixture C was significantly greater than for mixtures A and B, and that there was no significant difference between A and B.

No significant effects of treatment upon fatness, skin-handling properties, or chest girth were observed.

The amounts of food offered to, and refused by, the cows on each treatment are shown in Table 6. The only appreciable refusal of concentrates was by one cow receiving mixture B in the last experimental period. She then refused an average of 2·4 lb. out of a daily allowance of $10\frac{1}{4}$ lb. of concentrates. Calculation showed that the cows received very slightly less starch equivalent and digestible protein than their requirements for maintenance and production according to the standards recommended by Woodman (9).

Table 6. *Total amounts of each food offered and refused*

Treatment	Offered (lb.) Concentrates	Offered (lb.) Hay	Offered (lb.) Kale	Refused (lb.) Concentrates	Refused (lb.) Hay	Refused (lb.) Kale
Concentrate A	4968	6951	11,340	—	191	401
Concentrate B	4968	6951	11,340	75	149	279
Concentrate C	4968	6951	11,340	—	186	383

DISCUSSION

The results of this experiment showed no significant differences in their effects upon milk yield between concentrates containing 10% of seaweed meals or $8\frac{3}{4}$% oatfeed and $1\frac{1}{4}$% salt. Although the treatment differences studied were relatively slight, the technique used was capable of measuring small effects upon yield as shown by the very low error in the analysis of variance. It is noteworthy that high-yielding cows, producing an average of 45·3 lb. milk/head/day over the whole experiment, were used, and the feeding records show that they were not overfed.

No significant differences in fat percentage occurred between the treatments, in contrast to the conclusions of Dunlop(4), in spite of feeding amounts of seaweed meal which averaged 1·3 lb./cow/day, a quantity considerably greater than was used by him.

It is difficult to account for the significant treatment effects upon solids-not-fat percentage. The significant interaction in the analysis of variance indicates that the effect was not consistent from group to group. Reductions in the intake of energy or protein lower solids-not-fat percentage(10), and it may be that the small differences observed in this experiment reflected a slightly lower availability of nutrients from the concentrates containing the seaweed meals.

This experiment indicates that, in practice, the nutritive value of the seaweed meals is no greater than that of a mixture of 7 parts oatfeed and 1 part common salt. In appraising the value of the seaweed meals in this way it should be remembered that the oatfeed-salt mixture had a starch equivalent of only 39—a low value for an ingredient of concentrate mixtures for dairy cows. This result is in accord with the relatively low nutritive value previously ascribed to seaweed meals by Senior *et al.* (3), and with the findings at the Rowett Research Institute(1,2).

Claims are sometimes made for beneficial effects upon the dairy cow, arising from the vitamin and high mineral content of seaweed meals, but supporting evidence is lacking.

In view of the cost of collection, the need for artificial drying, the low palatability and relatively low nutritive value of seaweed meals, the practical value of these materials in the feeding of dairy cows appears to be very limited at the present time.

SUMMARY

The relative effects upon milk yield and composition of three concentrate mixtures containing 10% of two types of seaweed meal (*Ascophyllum nodosum* and *Laminaria cloustoni*) and an oatfeed-salt mixture, have been observed.

Each cow received daily a basal ration of 30 lb. marrowstem kale and 18 lb. hay for maintenance and the first $1\frac{1}{2}$ gal. of milk and $3\frac{1}{2}$ lb. concentrates for each gallon thereafter.

No significant effects of treatment upon milk yield or fat percentage were observed.

The milk produced on the oatfeed-salt mixture had a slightly but significantly higher solids-not-fat content than that on the mixtures containing seaweed meals.

The results showed that seaweed meals have a nutritive value no greater than that of a mixture of 7 parts oatfeed and 1 part salt, which had an estimated starch equivalent of only 39.

In view of the relatively high cost, low palatability and low nutritive value of seaweed meals, their possible use in the feeding of dairy cows appears very limited.

We should like to thank Mr W. D. Hay, O.B.E., B.Sc., Director of the Ministry of Agriculture and Fisheries Bridget's Experimental Husbandry Farm, Martyr Worthy, nr. Winchester, Hants, for his willing co-operation in providing facilities, and the farm staff for their help in carrying out this experiment.

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PATAGONIAN SEAWEED AS AN ALIMENTARY SUPPLEMENT FOR SHEEP

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Summary

The feeding of experimental groups of Corriedale lambs with rations containing 100, 200 and 300 g of dried unwashed seaweed of the *Macrocystes pirifera* variety for a period of 60 days produced no toxic effects.

Administered as the only ingredient of a ration, the seaweed proved to be unpalatable, but when included in the diet in an amount not exceeding one-third of the entire ration, it was consumed without any major difficulty.

No variations were found in the blood levels of calcium, magnesium, phosphorus, urea, and total protein, nor in the number of red corpuscles or the hemoglobin values.

Ruminal pH and the abdominal circumference were also unaffected.

No digestive disturbances or alterations of the reproduction process were observed.

Physical analyses were made of the wool grown before and after the administration of the seaweed, with consideration of medium fineness, uniformity of fineness, staple length, crimp, strength and flexibility. No significant differences were observed.

It can be deduced that the use of *Macrocystes pirifera* seaweed is completely harmless to the health of the animals.

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In our country, on the coast of Patagonia, there abounds a variety of giant *Macrocystes pirifera* seaweed, which is commonly called "cachiyuyo".

In this same region, millions of sheep are bred. Generally, during the winter months, these animals suffer, due to the lack of pastures, from a temporary denutrition, which affects them considerably and causes repercussions in the economic results of the exploitation of these animals.

It is interesting that all the sheep-raisers of Patagonia, upon recognizing the possibility of using the seaweed as a

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supplement for the alimentation of their sheep, wished to know exactly the benefits or dangers which might arise from its use, at least during the months when grazing lands are scarce.

From some years now, in countries withextensive coastal areas, such as Japan, Norway, Great Britain, the United States, etc., investigations have been in progress on the possibilities of utilizing the seaweed which abounds on these coasts as a source of food (1), (2).

Powell et al., (3) have conducted experiments on its use as a source of human nourishment, arriving at the conclusion that it is necessary to improve its palatability and digestibility.

Morimura et al. (4) mixed the seaweed with various foods, thus increasing its protein, lipide, mineral and vitamin value.

The chemical composition of seaweed has been shown to depend upon the species, the time and place that it was picked, but it is always within suitable values for its being used as an alimentary supplement (5).

As for its toxicity, only in large quantities does it produce gastro-intestinal symptoms, which disappear when it is removed from the diet.(3).

In respect to its use as food for animals, tests have been made, in various countries, in order to determine its toxicity and palatibility.

Berry et al. (6) did not obtain beneficial effects when they fed calves and milk cows with a seaweed flour.

However, other authors (7), using other types of seaweed, found an increase in the fat of the milk of the cows, and further, in the growth of chickens, an improvement similar to that obtained in giving them grasses in their food. They also determined that a ration with more than 50% seaweed was not accepted by the animals, and that its digestibility was low.

This first test, using the Macrocystes pirifera seaweed as a supplement to a basic diet for sheep, was made in order to determine its palatability, toxicity, effects on the digestive system, and as an orientation test on the influence of the seaweed on the nutrition.

Materials and Methods

Twelve lambs of the Corriedale P.P.C. species were selected, all of similar age, body weight and wool production. The animals were identified and separated with phenotiazine several days before the commencement of the experiment. The animals were divided into four equal groups in respect to weight and production of wool, as can be seen in table 1.

All the animals were shorn before the experiment was begun, and at the end of the same, samples of wool were taken from the areas of the shoulder-blade, ribs, and quarter.

The analyses of the fleece of each animal (total wool) were compared with those of the samples (wool after two months, grown during the feeding with seaweed), in order to ascertain what influence the administration of the seaweed might have had on the quality of the fiber.

TABLE 1

Body weight and weight of the fleeces of the animals

Lotes	Animal nº	Peso vivo (kg)	Peso vellón (kg)	Peso vivo por lote (kg)	Peso vellón por lote (kg)
1........	16	32,750	4,000		
	2	42,500	4,500	121,000	13,250
	23	45,750	4,750		
2........	25	40,500	4,000		
	10	43,750	4,500	119,750	13,250
	1	35,500	4,750		
3........	28	32,750	4,000		
	3	42,250	4,500	117,500	13,250
	20	42,500	4,750		
4........	11	48,750	4,000		
	24	35,500	4,500	121,750	13,250
	14	37,500	4,750		

Key:
1.= group 2.= animal no. 3.= body weight 4.= weight of fleece
5.= body weight of entire group
6.= fleece weight of entire group

The physical analyses made included the following measurements: medium fineness and uniformity of fineness, staple length, crimp for every 25 mm, strength and flexibility.

Each lot was placed in equal stalls, with cement floors, pasture both edible and potable, all receiving the same handling and basic feeding.

According to F.B. Morrison, in his work "Food and Feeding of the Sheep", edition 1951, the daily requirement per head of lambs of one year of age and an average weight of 40 kg are the following:

Dry material................................1.0 to 1.3 kg
Digestible protein..........................0.08 to 0.10 kg
Total of digestible nutrients...............0.68 to 0.82 "

In accord with these data, we fed the animals with a ration which provided only for their subsistence, based on ground grains of sorghum (var. E. Kalo), cakes of linum (30-33% protein) and oat stalks; the sum of their respective values was:

Dry matter..................................1.0 kg
Digestible protein..........................0.08 kg
Total of digestible nutrients...............0.81 kg

With the addition of seaweed to the rations of groups 1, 2 and 3, we provided for the supplementary introduction of minerals which varied according to the amount of seaweed, and differentiated these groups from the control group, which did not receive the seaweed.

The analysis of these diets can be seen in table 2.

TABLE 2

	Sorgo con torta de lino	Paja de avena
Humedad g %/o g	11,30	6,50
Materia seca g %/o g	88,70	93,50
Cenizas g %/o g	4,35	9,38
Cenizas insolubles g %/o g en HCl al 5 %/o	0,71	0,63
Nitrógeno g %/o g	2,74	0,71
Proteínas (N × 6,25) g %/o g	17,21	4,4
Extracto etéreo g %/o g	6,99	0,97
Extracto no nitrogenado g %/o g	60,15	78,75

Key:
1.= Moistness 2.= dry matter 3.= ashes 4.= insoluble ashes
5.= nitrogen 6.= proteins 7.= ether extract
8.= non-nitrogenated extract
a.= sorghum with linum cake b.= oat stalks

The seaweed used was provided by INTI*, unwashed and ground in fat; it was mixed with the rations in concentrations of 100, 200 and 300 g per day and per head and administered to groups 1, 2, and 3 respectively. Group no. 4 (control) was given 20 g of bone flour, per day and per head. Since the seaweed is rich in minerals, the bone flour was added so that all the rations should contain a sufficient amount of minerals, or even an excess; allowing then, as the single factor to be considered, the protein level of the rations, which would differ with the addition of seaweed.

The bone flour used in the food of group no. 4 was of the following composition:

Moistness	0.85 g%g
Total ashes at 600°C	96.23 g%g
Insoluble ashes	3.50 g%g
Calcium	41.36 g%g
Phosphorus	17.75 g%g

In table 3 we can see the results of the various analyses to which the Macrocystes pirifera was submitted, comparing them with the values obtained from the same variety in Ireland.

*On the 26th of April, 1961, an agreement was made with the National Institute of Industrial Technology which, among other proposals, includes that of supporting the investigation of subjects such as that treated in this work.

TABLE 3

Comparative table of the analytical values obtained from the variety Macrocystis pyrifera of different origins

	Galway (Irlanda)	Facultad C. E. y N.	I. B. A. molidas	I. B. A. sin moler
Cenizas g °/o g	26,77 a 44,66	36,8	39,4	38,8
Nitrógeno total g °/o g	1,03 a 1,63	—	1,63	1,41
Hidratos de carbono (como almidón) g °/o g	—	3,4	5,6	5,1
Fibra cruda g °/o g	4,98 a 12,57	7,5	—	—
Extracto etéreo g °/o g	1,65 a 2,05 *	0,35	—	—
Acido algínico g °/o g	19,00 a 27,10	21,0 a 24,0	—	—
Fucoidina g °/o g	15,00	15,2	—	—
Laminarina g °/o g	0,10 a 0,50	0,12 a 0,52	—	—
Iodo g °/o g (como INa)	0,12 a 0,38	0,15 a 0,52	—	—
Calcio g °/o g (como OCa)	5,30 **	1,53	1,29	1,27
Magnesio g °/o g (como OMg)	5,50 **	1,29	1,32	1,34
Sodio g °/o g (como ONa_2)	5,47 **	11,27	11,32	11,05
Potasio g °/o g (como OK_2)	39,40 **	28,23	26,49	26,49
Fósforo g °/o g (como P_2O_5)	5,56 **	1,60	1,83	1,32
Manganeso mg °/o g (como Mn)	—	0,15	0,12	1,00
Cobre (como OCu) mg °/o g	—	1	0,32	0,20
Cobalto mg °/o g	—	—	0,065	0,065
Hierro g °/o g (como Fe_2O_3)	0,16 **	1,11	—	—
Cloruros g °/o g (como ClNa)	35,26 **	13,4	14,7	12,8
Sulfatos g °/o g (como SO_3)	0,86 **	1,0	—	—

Key:
1.= ashes g/g 2.= total nitrogen 3.= carbohydrates (starch)
4.= crude fiber 5.= ether extract 6.= alginic acid
7.= fucoidine 8.= laminarine 9.= iodine 10.= calcium
11.= magnesium 12.= sodium 13.= potassium 14.= phosphorus
15.= manganese 16.= copper 17.= cobalt 18.= iron
19.= chloride 20.= sulfate

For one week, the four groups were kept in their respective stalls, accustoming themselves to the atmosphere and the new diet, since the animals had always been in the field. In order for them to learn to eat the new rations, it was necessary to place, as an example, an animal already used to the food into each box. The concentrations were administered in the morning, and the oats in the afternoon, all weighed exactly, and in the case that leftovers were found on the following day, they were removed. The water was administered according to the wants of the animals, and no litter was made for them, in order to prevent the possibility of their eating it.

The classification of the seaweeds used was done according to the method of the Institute, under the direction of professor Oscar Kühnemann.
* The extraction was done with petroleum ether.
** These data refer to analysis of ashes.

The day of the initiation of the experiment, all the animals were weighed. Observations of the condition of the lambs and their excretions were made daily. The abdominal circumference of each was measured, first on an empty stomach, and then 1 to 4 hours after the administration of the concentrated rations. (Table 4).

TABLE 4

Measurement of the abdominal circumference before the administration of the seaweed ration, and 1 and 4 hours afterwards

	Antes de racionar	1 hora después	4 horas después
Lote nº 1:			
Borrega 16	101,0 cm	101,0 cm	103,0 cm
» 2	109,5 »	117,0 »	114,0 »
» 23	105,5 »	112,0 »	112,5 »
Lote nº 2:			
Borrega 1	106,5 »	111,5 »	115,0 »
» 25	109,0 »	111,0 »	110,5 »
» 10	101,5 »	109,0 »	109,5 »
Lote nº 3:			
Borrega 28	106,0 »	112,0 »	109,5 »
» 3	113,0 »	119,5 »	122,0 »
» 20	113,5 »	121,0 »	116,5 »
Lote nº 4:			
Borrega 24	102,0 »	104,5 »	102,5 »
» 14	100,0 »	106,5 »	108,0 »
» 11	118,0 »	121,0 »	119,0 »

Key:
a.= before feeding b.= 1 hour after c.= 4 hours after

Note: The measurements are the average of 3 consecutive days, and were taken at the height of the umbilicus.

By means of a stomach tube, ruminal liquid was extracted before and after the administration of the rations, and the pH of the same was determined. (Table 5).

Microscopic analyses were made of the fecal matter, in order to determine the presence or absence of parasites; and further to observe to what degree the pieces of seaweed are digested in the course of their passage through the digestive tract of the sheep.

Thirty and sixty days after the beginning of the experiment, the animals were again weighed individually. Then they were again let out into the fields. Eight days later, groups 3 and 4 were placed back in the stalls, where they were fed exclusively on unwashed ground seaweed, in order to determine whether the animals already accustomed to eating them with their rations (group 3) and the animals which had never tried them (group 4), would eat them, and how long it would take them to do so.

TABLE 5

pH values of the ruminal liquid of sheep fed with and without seaweed

Borrega nº	pH (en ayunas)	pH (3 horas después de comer algas)	pH (6 horas después de comer algas)
23 (lote 1)	6,7	6,7	7,0
10 (lote 2)	7,4	6,4	6,6
20 (lote 3)	7,0	6,4	7,0
11 (lote 4)	6,4	6,3	6,3

Key:
a.= no. of lamb b.= pH (on empty stomach)
c.= pH (3 hours after eating seaweed)
d.= pH (6 hours after eating seaweed)

Note: The ruminal liquid was extracted through a stomach tube without being filtered; the pH was determined immediately by the colorimetric method, using the universal indicator of Merck.

When this last experiment, which lasted only 5 days, was finished, all the sheep were mated with a single ram, in order to enable us to observe what influence the food administered during the experiment could have had on the occurrence of heat, the percentage of pregnancies, and on parturition.

At the beginning and the end of the experiment, we made analyses of the hemoglobin (Salhi method), recount of the red corpuscles, and calcium, according to the method of Marenzi and Gerschman (8), phosphorus according to the method of Fiske and Subbarow (9), magnesium according to Marenzi's modification of the Briggs method (10), urea according to the method of Ambard (11) and of total protein according to the method of Kingsley (12). (See table 6).

Results

With respect to the palatability of the dried, ground and unwashed seaweed, the experiment which was made with groups 3 and 4 to complete the tests, confirms that the animals refuse to eat

TABLE 6

Comparative values of the blood analyses of the animals at the beginning and end of the experiment.

Borrega n°	Hemoglobina		Hematies		P mg % ml		Ca mg % ml		Mg mg % ml		Urea mg % ml		Proteinas mg % ml	
	I	F	I	F	I	F	I	F	I	F	I	F	I	F
2......	78	71	6.610.000	6.640.000	7,4	6,2	11,8	12,1	1,9	2,0	40,0	37,4	5.67	6.24
16......	108	76	7.210.000	6.050.000	4,6	9,9	10,9	11,9	2,1	1,8	39,8	36,2	5,89	7,02
23......	76	70	6.230.000	8.450.000	6,8	7,0	11,6	9,8	1,8	2,1	45,4	41,3	6.02	6,25
3......	76	80	7.230.000	8.040.000	6,2	7,3	12,3	9,3	2,2	2,0	42,1	40,5	7.21	5,89
20......	86	83	6.000.000	9.960.000	8,0	8,5	11,1	11,8	1,8	1,7	41,2	43,1	4.28	6,23
28......	66	70	9.140.000	8.000.000	8.5	7,1	10,9	10,1	1,9	1,8	41,8	44,2	5.16	5.21
11......	82	82	6.860.000	10.380.000	7,4	8,8	10,8	12,3	1,8	2,1	41,3	41,6	6,41	6,84
14......	68	74	9.300.000	10.640.000	8,5	7,0	11,4	11,2	2,0	1,7	45,4	48,2	5,62	6,21
24......	78	80	7.100.000	10.030.000	5,6	5,8	10,9	11,1	1,7	1,8	46,2	39,5	5.29	4.93
1......	86	78	5.120.000	6.850.000	7,4	7,0	11,2	10,8	2,4	2,0	38,2	39,4	6.23	7.20
10......	78	83	5.860.000	7.530.000	7,6	6,8	12,4	11,4	1,6	1,9	35,4	40,1	4,89	6.13
25......	78	76	10.280.000	8.490.000	8,5	7,2	11,3	11,9	1,8	2,1	42,8	46,3	5.42	5,59

I. - at the beginning of the experiment
F.= after 60 days

it if it is given them as their only food. In effect, the animals refuse to eat it for the first 3 days, even though they have no other food available. Due to this, on the following days, small quantities of corn seed (group 3) and some leaves of alfalfa hay (group 4) are added. Then it can be seen that the sheep of both groups, already very hungry after the first three days, during which they have voluntarily fasted, so to speak, by refusing to eat the seaweed, carefully separate the pieces of seaweed from the rest of the food, in order to eat only the seeds and the alfalfa leaves. On the other hand, if the seaweed is mixed well with the other palatable ingredients, and if it does not exceed one third of the entire ration, the sheep consume it completely. This was demonstrated clearly during the week of acclimatization, before the beginning of the tests, when all the animals managed to consume the rations of concentrates completely, though with greater rapidity according to the lesser or greater percentage of seaweed in them.

The daily observations of the condition and aspect of the animals, as well as the measurement of the abdominal circumference, the determination of the pH of the ruminal liquid and the analysis of the feces, allow us to confirm that the feeding with seaweed had no noxious effects, especially in relation to the digestive process.

Both the measurements of the abdominal circumference and the pH values of the ruminal liquid always hover within the normal values (see tables 4 and 5).

We can make several interesting observations concerning the fecal matter: the animals that consume the seaweed defecate two or three times more than is normal, the feces being joined in clumps and of a shining aspect, though normal in color.

An analysis of the feces of sheep nos. 10, 14, 20 and 23 was made thirty days after the commencement of the tests. They were found to be practically free of parasites, though in the feces of nos. 10 and 23 we observed a regular quantity of undigested pieces of seaweed.

Although the amount of seaweed administered contained in general more enzymes than recommended, no toxic influence was observed.

The results of the blood analyses can be seen in table 6.

All the results obtained are found to be within the normal limits, and the differences observed do not permit us to draw any conclusions concerning the effect which the feeding with seaweed could have on their composition.

The physical analyses made of the wool which was grown before and after the administration of the seaweed, yielded no significant differences, neither within nor among the various groups.

The results of the several weighings are shown in table 7.

It can be seen that, with the exception of the animals of groups 3, which ate 300 g of seaweed per day and per head, the others underwent very little variation of weight during the months of the experiment. Nonetheless, given the small amount of animals in the experiment, we do not believe it is quite prudent to draw any definitive conclusions in this respect, especially as the control lot revealed an increase slightly greater than that of the groups that received seaweed in quantities of 100 and 200 g per day and per head.

According to what has been said previously, the basic rations of the four lots only provided the nutrients necessary for subsistence, while the supplementation with seaweed for the first three lots provided an extra amount of proteins, varying according to the group. The results obtained concerning the increases in weight and the analyses of the wool do not appear to demonstrate that the proteins introduced in the seaweed had any influence on these two aspects considered.

TABLE 7

Results of the weighings

Animal nº	Peso inicial (kg)	Peso a los 30 días (kg)	Peso a los 60 días (kg)	Diferencia final (kg)	Ganancia de peso del lote en 60 días (kg)
Lote nº 1 :					
16..........	32,750	33,750	34,250	1,500	
2..........	42,500	48,000	46,250	3,750	6,250
23..........	45,750	47,500	46,750	1,000	
Totales ...	121,000	129,250	127,250		
Lote nº 2 :					
1..........	35,500	36,750	38,250	2,750	
25..........	40,500	44,000	45,000	4,500	6,750
10..........	43,750	40,500	43,250	—0,500	
Totales ...	119,750	121,250	126,500		
Lote nº 3 :					
28..........	32,750	35,500	39,250	6,500	
3..........	42,250	47,000	49,500	7,250	25,750
20..........	42,500	48,500	54,500	12,000	
Totales ...	117,500	131,000	143,250		
Lote nº 4 :					
24..........	35,500	36,000	37,250	1,750	
14..........	37,500	38,000	37,500	—	8,000
11..........	48,750	50,250	55,000	6,250	
Totales....	121,750	124,250	129,750		

Key:
a.= animal no.   b.= initial weight   c.= weight after 30 days
d.- weight after 60 days   e.= final difference
f.- weight gain of the group in 60 days

However, we should consider the following: at the beginning of the experiment, the animals were in very good nutritional condition; thus, it can be supposed that, since the basic ration given them served only for subsistence purposes, it is logical to think that the reserves which they had allowed them to avoid any deficiencies they might have incurred during the months of the experiment. To this should be added that the amount of digestible protein which the rations of seaweed could have introduced could not have any decisive influence, as appears from these tests, if we analyze exactly its influence on the increase in weight and production of wool.

Once having completed the stabilizing controls, the sheep were let out into the field and mated for 45 days, during which time all became pregnant. No abnormality was observed during the period of gestation, and all bore normally.

Conclusions

In accordance with the principal objectives which motivated these experiments and the results explained, the following conclusions can be made:

1) The _Macrocystes pirifera_ variety of seaweed, unwashed, dried and ground, is not palatable to the sheep unless it is administered mixed with other ingredients which are palatable, such as, for example, oleaginous seeds and/or cakes. Given alone or in a proportion greater than 30-35% in a ration, it is refused by the sheep, even after several days without eating.

2) If it is administered in quantities of 100 to 300 g per day and per head, for at least 60 days, mixed with concentrates, it provokes no digestive abnormalities, such as constipation, diarrhea, indigestion, abnormal fermentation, etc. Notwithstanding, the feces increase in size and change in aspect.

3) The seaweed is digested well, for the most part, by nearly all the animals.

4) The pH of the ruminal liquid, determined before and after the ingestion of the seaweed, reveals no variations of importance, which fact allows us to deduce that their component substances do not affect the rumen.

5) Although the seaweed is very hygroscopic in the state in which it is administered, and the animals always have water at their disposition, we observed no abnormal dilatations of the stomach and intestines.

6) The food supplemented with seaweed had no influence on the composition of the blood, as far as concerns the erythrocyte number and the quantity of hemoglobin. The same is true of the phosphorus, calcium, magnesium, urea and protein levels of the serum.

7) Although the group fed with seaweed in a quantity of 300 g per day and per head, showed the greatest increases in weight, either individually or collectively, the small number of animals used prevents us from drawing definitive conclusions on the nutritive properties of the seaweed tested. However, on the other hand, this serves to demonstrate once more the innocuousness of the seaweed, even in relatively large quantities.

8) Feeding with seaweed has no noxious influence on the reproductive sphere, as confirmed by the normal conception, gestation and parturition of all the animals.

9) The analyses made in order to determine the composition of _Macrocystes pirifera_ show that it has a quantity of proteins amounting to 7.5% or 10.2%, of minerals between 26.77 and 41.6%.

This lends some significance to the possibility of its being used as a nutritive supplement in those regions where there is nothing better and more economical.

10) In order to make it definitively clear what possibilities there would be of using seaweed as a food for sheep in some patagonian regions, it would be necessary to conduct new experiments in these same regions and under the same conditions to determine the following:

a) Advantages and disadvantages of its administration, with special reference to the restrictions that can arise from its manipulation (extraction, washing, drying, grinding, transport, marketing, etc.).
b) Nutritive qualities of the seaweed as a subsistence, and even fattening, ration, in cases of lack of pastures.

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THE EFFECT OF FEEDING DIFFERENT SEAWEED MEALS ON THE MINERAL AND NITROGEN METABOLISM OF LAYING HENS

By C. J. E. HAND* and C. TYLER

Three different seaweed meals, *Laminaria cloustoni*, *Ascophyllum nodosum* and *Laminaria saccharina*, were fed to poultry in three different experiments. In each experiment levels of 10% and 20% in a basal ration were compared with the basal ration itself.

When the seaweed was low in energy the birds showed loss in weight or lowered egg production or both. The high chloride intake when the ration contained seaweed resulted in a greatly increased water intake and a heavy excretion of both chloride and water, but this did not appear to affect the general health of the birds. Changes observed in calcium, phosphorus and nitrogen retentions and balances could be explained on the basis of changes in egg production. The seaweeds had no effect on the chemical composition of egg content and shell, nor on porosity and shell thickness. On the basis of these criteria seaweed meals therefore had no beneficial effects and at the higher level of 20% were detrimental in some respects.

In a further, long-term feeding experiment *Laminaria cloustoni* (stipe), *Laminaria cloustoni* (frond) and *Ascophyllum nodosum* were fed at levels of 10% and 15%, each level being given for 100 days. The results, as far as they were comparable, supported the more detailed balance experiments.

Introduction

From time to time the question has arisen as to whether seaweed could usefully be fed to poultry, and Miller & Bearse,[1] Sumita, Kuwabata & Fujoka,[2] Batt[3] and Black[4] have reported feeding experiments with seaweed. The general position seems to be that poultry show no adverse effects when reasonable quantities are fed: the palatability of the ration may be improved and there is an increase in the iodine content of the egg. On the other hand, Lunde[5] suggested that the high chloride content of seaweed meal is probably a limiting factor in its use.

As far as the authors are aware, no balance experiments have been carried out using rations containing seaweed meals and it was therefore decided to carry out such experiments, determining the balance of calcium, phosphorus, chloride and nitrogen, while at the same time recording more general data about the birds and their eggs.

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Three types of seaweed meal, namely, *Laminaria cloustoni*, *Ascophyllum nodosum* and *Laminaria saccharina*, were used and this paper deals with experiments covering all three types.

Experimental

Birds

Four Rhode Island Red pullets were obtained fresh from the University Farm for each experiment. The pullets were in lay or just about to lay when put into the cages and the experiment began when all were laying regularly. Each bird was housed separately in the usual type of poultry metabolism cage.

Plan of the experiments

Table I shows the plan of the experiments, 10% and 20% levels of the appropriate seaweed being introduced at different times with adequate control periods (C) before and after each seaweed feeding period (S). There were thus five periods which have been named C1, S2, C3, S4 and C5.

Table I

General plan of the experiments

Period	Symbol	Daily regime
Control	C1	120 g. of basal ration
Seaweed	S2	108 g. ,, ,, ,, + 12 g. of seaweed meal
Control	C3	120 g. ,, ,, ,,
Seaweed	S4	96 g. ,, ,, ,, + 24 g. of ,, ,,
Control	C5	120 g. ,, ,, ,,

In each case a mineral supplement of 5 g. of calcium carbonate and 0·5 g. of sodium chloride was given.

Duration of the experiments

The first experiment lasted 70 days, i.e., 14 days per period, whilst the second and third experiments lasted 80 days, i.e., 16 days per period.

Time of the experiments

Experiment 1 was carried out in May, June and July, Experiment 2 in June, July and August and Experiment 3 in April, May and June.

Ration

The basal ration used throughout consisted of 39 parts of middlings; 34 parts of barley meal; 18 parts of crushed oats; 18 parts of bran; 12 parts of maize gluten meal; 6 parts of fish meal and 1 part of cod liver oil. Different consignments of the ration naturally varied on analysis but not to a very great extent and Table II shows the average analysis for all three experiments. In the same table the analysis of the seaweeds is also shown.

Table II

Average analysis of the dry matter of the basal ration and of the three seaweed meals

	Basal ration %	*Laminaria cloustoni* %	*Ascophyllum nodosum* %	*Laminaria saccharina* %
Crude protein	18·59	14·12	10·25	4·15
Ether extract	3·62	1·30	1·90	0·31
Crude fibre	8·48	5·40	3·50	4·80
Nitrogen-free extract	64·16	37·90	60·85	72·54
Total ash	5·15	41·28	23·50	18·20
Insoluble ash	0·53	0·54	0·32	0·21
Calcium	0·50	1·21	1·26	1·48
Phosphorus	0·94	0·36	0·12	0·13
Chloride	0·15	13·82	5·56	5·95
Moisture	13·41	7·20	10·80	8·18

During the control periods 120 g. of the basal ration were mixed with 5 g. of calcium carbonate and 0·5 g. of sodium chloride, and the mixture then made into a crumbly mash by the addition of 100 ml. of water. This constituted the daily ration with drinking water *ad lib.* In the two seaweed feeding periods of each experiment the appropriate quantity of seaweed meal replaced a corresponding weight of basal ration, to produce respectively rations containing 10 and 20% of seaweed. The resulting 120 g. were then mixed with calcium carbonate, sodium chloride and water as before. In each case the seaweed had been dried and ground to pass a 60-mesh sieve. *Laminaria cloustoni* was given in the first experiment, *Ascophyllum nodosum* in the second and *Laminaria saccharina* in the third.

The food was fed at 9.30 a.m. each morning and fresh distilled water was given. At the same time food and water residues were collected and measured, along with droppings, eggs and feathers, if any. Care was taken to see that adequate drinking water was always available and records of all supplies were kept.

Methods of analysis

The analytical methods for calcium, phosphorus, chloride and nitrogen were, with only slight modifications, the same as those described by Tyler.[6]

Other measurements

Shell thickness was measured on five pieces of true shell (Tyler & Geake[7]) using a micrometer screw gauge and the mean taken. Porosity coefficients for the eggs were obtained using the method of Tyler.[8]

Treatment of the data

Individual daily intake and output values and individual egg measurements were made, and then the mean daily value for each period, namely, three control and two seaweed periods, was calculated for each bird. It was these daily means for four birds and five periods which were used for the analysis of variance. However, the amount of data is so great that in the tables, only the general period means each covering the four birds are shown, i.e., bird-day means. When calculating significant differences the bird-day mean for a seaweed period was always compared with the mean of the two control period means which came immediately before and after this seaweed period. Thus period S2 was compared with the mean of C1 and C3 designated period C_{13} and period S4 with the mean of C3 and C5, designated period C_{35}.

In this way it was hoped to reduce the effects, if any, caused by temporal changes.

Significant differences are shown in the usual way: N.S., *, ** and *** represent, respectively, not significant, significant at $P < 0.05$, at $P < 0.01$ and at $P < 0.001$.

Occasionally reference will be made to data for sub-periods, each of which represents half a full period, and also to daily data, but none of these values is given except where they are necessary to amplify the discussion.

Definition of terms

Retention.—By 'retention' is meant the difference between the intake of a substance and the output of that substance in the droppings. The use of this term is made necessary by the fact that the term 'absorption' cannot be used since poultry excrete urine and faeces together.

Balance.—The term 'balance' will therefore refer to the intake of a substance minus the total outgo of that substance including eggs:

i.e., $$\text{Balance} = \text{Intake} - (\text{outgo in droppings} + \text{eggs})$$

Clearly, retention and balance will be the same if no eggs are laid, and retention minus outgo in eggs will give the balance figure:

i.e., $$\text{Balance} = \text{Retention} - \text{outgo in eggs}$$

Results

General health of the birds

All the birds in Experiments 1 and 2 remained in good health throughout the whole of the experiment. During control periods droppings were normal, but during seaweed periods they became greener and also more watery. The watery consistency was caused by the consumption of larger quantities of water, as will be seen later. Despite this and the increased intake of chloride there was no deterioration in health.

The same can be said for birds 1, 2 and 3 in Experiment 3, but bird 4 was the exception. She appeared healthy in periods C1 and S2, egg production began to decrease in period C3 and food consumption suddenly dropped at the beginning of period C5 and she died on day 75 of the experiment. A post mortem examination revealed extensive lymphomatosis. Since this condition may have begun to develop earlier than was suspected, it was decided not to use the data for her in the statistical analysis, and therefore for Experiment 3 the results refer to three birds only.

With regard to the shedding of feathers, this was only of a measurable degree with the birds in Experiment 2. It began around the beginning of period S4 and continued to the end of the experiment and may have been caused by the 20% level of seaweed, or the high temperatures obtaining during period C3 or a combination of both.

Food intake

If all the food fed was consumed then the intakes of the constituents under investigation were as shown in Table III. From these values it will be observed that between experiments, the control rations showed very little variation. Further, it is seen that, in each case, the addition of seaweed slightly increased the amount of calcium and decreased the amount of phosphorus and nitrogen and that chloride values were most affected, a considerable increase occurring in Experiments 2 and 3 and a very great increase in Experiment 1.

Table III

Amounts of calcium, phosphorus, chloride and nitrogen present in the daily rations (g.)

	Ca	P	Cl	N
Experiment 1				
Controls C1, C3, C5	2·53	1·01	0·42	3·03
Seaweed S2 10%	2·61	0·95	1·95	2·98
Seaweed S4 20%	2·68	0·89	3·48	2·92
Experiment 2				
Controls C1, C3, C5	2·48	0·97	0·46	3·06
Seaweed S2 10%	2·56	0·88	1·04	2·95
Seaweed S4 20%	2·64	0·80	1·62	2·84
Experiment 3				
Controls C1, C3, C5	2·42	0·96	0·45	3·19
Seaweed S2 10%	2·54	0·88	1·09	2·95
Seaweed S4 20%	2·66	0·80	1·73	2·71

With regard to actual consumption, all the birds in Experiments 1 and 2 ate the whole of their ration each day and in Experiment 3 birds 1, 2 and 3, the only ones to be considered, also ate all their food. Throughout each of the experiments it was noticed that the birds ate their food far more eagerly when it contained seaweed, which suggests that it had a greater palatability.

Water consumption

This is defined as the amount of water drunk plus the amount consumed with the wet food, but, of course, this latter addition is an almost constant quantity. Table IV shows the results and it is quite clear that seaweed feeding increased the water consumption, the increase being significant in all except one case. Further, the increase was always greater with the greater quantities of seaweed. The increased intake was related to chloride content, the largest increases occurring in Experiment 1 where the seaweed highest in chloride was fed.

The high value for water consumption in period C3 of Experiment 2 compared with periods C1 and C5 was almost certainly caused by the high temperature prevailing at that time. It should also be pointed out that individual birds showed considerable variations in water consumption and that one bird receiving the highest levels of chloride actually consumed over 1000 g. of water on certain days.

Table IV

Water consumption per period (g.). Bird means

Period	Expt. 1	Expt. 2	Expt. 3
C1	429	480	337
S2	619	557	434
C3	484	583	350
S4	904	672	565
C5	492	495	373
$S2 - C_{13}$	+ 163*	+ 26 N.S.	+ 91**
$S4 - C_{35}$	+ 416***	+ 133*	+ 204***

Live weight changes

The bird means for changes in live weight are recorded in Table V.

Table V

Live weight changes per period (g.). Bird means

Period	Expt. 1	Expt. 2	Expt. 3
C1	− 42	− 7	− 89
S2	− 71	− 16	− 97
C3	+ 57	+ 58	+ 1
S4	− 156	− 120	− 42
C5	+ 99	+ 84	+ 22
$S2 - C_{13}$	− 79 N.S.	− 42 N.S.	− 53 N.S.
$S4 - C_{35}$	− 234***	− 191*	− 54 N.S.

In Experiment 1 the feeding of 10% seaweed caused a considerable decrease in live weight but this change was not significantly different from the change in control periods C1 and C3. However, this was caused entirely by the behaviour of bird 1, and if the values for birds 2, 3 and 4 only were taken then the result was a highly significant loss in period S2 compared with the average for period C_{13}. At the 20% level of seaweed feeding, the loss in weight was highly significant. This reduction in live weight may be explained as follows. The ration fed during the control periods had a calculated starch equivalent sufficient for maintenance and about 70% egg production, according to the requirements quoted by Halnan.[9] The addition of seaweed probably resulted in a lowering of the starch equivalent. At the lower level of seaweed feeding the birds generally maintained the same level of egg production as in the control periods (see section on Egg production) but suffered a loss in weight, whilst at the higher level of seaweed feeding, which would mean an even lower starch equivalent, the birds showed a greater loss in body weight and also a reduced egg production.

In Experiment 2, losses in weight occurred in the seaweed periods but only the 20% level caused a significant decrease. With individual birds the decrease was greater if egg production was maintained. The seaweed used in this experiment, *Ascophyllum nodosum*, also had a composition such that its substitution for part of the ration would probably reduce the starch equivalent intake, so that the explanation of the live weight changes may be the same as for Experiment 1.

The results for Experiment 3 show that although losses in weight occurred when seaweed was given, yet they were not significantly different from the changes occurring in the control periods. The seaweed used, *Laminaria saccharina*, had a much higher laminarin content (26·5%) than the other two seaweeds (0·4% and 3·5%, respectively) and it may be that this seaweed did not greatly reduce the starch equivalent intake and therefore did not lead to significant weight losses. It certainly did not interfere with egg production as greatly as did the first two meals.

Egg production

The results for Experiment 1 (Table VI) show that the 10% level of seaweed feeding did not produce any significant effect on egg production, but that the 20% level caused a significant reduction. As suggested in connexion with live-weight changes, this reduction coupled with weight losses may have been caused by the lower starch equivalent of this ration.

Table VI

Egg production per period. Bird means

Period	Expt. 1	Expt. 2	Expt. 3
C1	10·50	10·00	11·67
S2	9·00	7·50	11·33
C3	8·75	7·50	10·67
S4	5·75	4·75	9·00
C5	7·25	1·75	10·67
$S2 - C_{13}$	− 0·63 N.S.	− 1·25 N.S.	+ 0·16 N.S.
$S4 - C_{35}$	− 2·25*	+ 0·13 N.S.	− 1·67 N.S.

In Experiment 2 only bird 3 remained in lay throughout the whole of the experiment, and generally there was a pronounced decline in egg production as time went on. It may be that here the 20% level of seaweed produced an effect on egg production which for some unknown reason carried over into the control period C5, or alternatively there may have been a natural seasonal decline.

However, none of the differences was significant.

In Experiment 3 there was quite a high egg production throughout and no differences were significant. This again supports the concept advanced earlier that this seaweed with high laminarin content did not greatly reduce the starch equivalent intake and hence did not interfere with egg production.

The values for mean egg weight have not been given, for no differences were significant apart from a significant decrease when 10% seaweed was fed in Experiment 1.

Calcium

The values for calcium retention and balance are shown in Table VII.

Table VII

Calcium retention and balance (mg.). Bird-day means

Period	Expt. 1		Expt. 2		Expt. 3	
	Retention	Balance	Retention	Balance	Retention	Balance
C1	1178	− 119	1094	+ 24	1335	− 139
S2	1068	− 48	879	+ 100	1314	− 90
C3	1046	− 35	910	+ 82	1308	− 1
S4	797	+ 126	649	+ 134	1206	+ 123
C5	933	+ 35	429	+ 235	1265	+ 45
$S2 - C_{13}$	− 44 N.S.	+ 19 N.S.	− 123 N.S.	+ 47 N.S.	− 8 N.S.	− 20 N.S.
$S4 - C_{35}$	− 193*	+ 126*	− 21 N.S.	− 25 N.S.	− 81*	+ 101 N.S.

In Experiment 1 there was a tendency for calcium retention to decline throughout the experiment as far as the end of period S4, and it then showed a slight recovery. There was, however, a significant difference when 20% seaweed was fed, the retention of calcium being considerably lower than the corresponding control periods. The balances were at first negative and later positive and the balance was significantly higher in the S4 period than in the C_{35} period. Before drawing any conclusions here about the effect of seaweed on calcium metabolism, it is important to note that Tyler[10] has shown that, over a period, there is a close relationship between calcium secreted as shell and calcium retained. Since egg production varied in this experiment and fell in the same way as the calcium retention, it is therefore probable that these changes in retention were simply a reflection of changes in egg production and hence in the amount of calcium lost from the body as shell. The relationship mentioned above is not such as to produce a constant balance and hence there is nothing in the change in balance to negative this concept.

There were no significant differences for either retention or balance in Experiment 2.

The results for Experiment 3 followed fairly closely on the lines of Experiment 1. However, any changes which did arise could be readily explained on the basis outlined above.

Phosphorus

From the results presented in Table VIII, it will be seen that in no experiment were there any significant differences either in retention or balance. The trends which actually occurred appear to have been caused by two sets of circumstances, firstly the lowered intake in the seaweed periods and secondly the increased excretion associated with shell formation. Both these factors will decrease retention and the small fluctuations in retention are thus readily explained.

Table VIII

Phosphorus retention and balance (mg.). Bird-day means

Period	Expt. 1 Retention	Expt. 1 Balance	Expt. 2 Retention	Expt. 2 Balance	Expt. 3 Retention	Expt. 3 Balance
C1	83	+ 2	92	+ 19	80	− 11
S2	91	+ 22	90	+ 35	73	− 11
C3	96	+ 30	95	+ 39	99	+ 21
S4	95	+ 54	82	+ 47	88	+ 23
C5	93	+ 39	136	+ 123	99	+ 26
$S2 - C_{13}$	+ 1 N.S.	+ 6 N.S.	− 4 N.S.	+ 6 N.S.	− 17 N.S.	− 16 N.S.
$S4 - C_{35}$	+ 1 N.S.	+ 19 N.S.	− 34 N.S.	− 34 N.S.	− 11 N.S.	− 1 N.S.

Chloride

In the case of chloride it will be remembered that there is a considerable increase in chloride intake when seaweed is fed, and this must be borne in mind when discussing the results.

The results (Table IX) are consistent for all three experiments. In every case there was a highly significant increase in the retention of chloride when seaweed was fed. Compared with their respective controls the higher level of seaweed feeding gave the greater increase in retention. It is also of interest to note that the retentions in periods C3 and C5 were considerably less than those in C1, and it would appear that during these periods the birds were getting rid of extra chloride which their tissues were compelled to store in the previous high-chloride periods.

Table IX

Chloride retention and balance (mg.). Bird-day means

Period	Expt. 1 Retention	Expt. 1 Balance	Expt. 2 Retention	Expt. 2 Balance	Expt. 3 Retention	Expt. 3 Balance
C1	75	0	65	+ 2	73	− 1
S2	108	+ 41	76	+ 26	94	+ 24
C3	29	− 36	33	− 16	44	− 19
S4	94	+ 51	61	+ 26	84	+ 31
C5	21	− 32	− 17	− 30	25	− 34
$S2 - C_{13}$	+ 56***	+ 59**	+ 27***	+ 33***	+ 35***	+ 34***
$S4 - C_{35}$	+ 69***	+ 85***	+ 53***	+ 49***	+ 49***	+ 58***

The balance values strongly support the ideas expressed above, since it is clear that in periods C3 and C5 the birds went into negative chloride balance. All the differences are highly significant.

The daily values (not given) showed very distinctly that the reaction to higher chloride intake was immediate, a greater water consumption and a greater chloride excretion occurring at once.

Nitrogen

It is apparent from the results in Table X that there was a significant fall in retention during the feeding of both levels of seaweed in Experiment 1 and with the higher level of feeding in Experiment 3. In the other cases there was also a fall but it was not significant.

The balance results indicate that none of the results was significant and that in some cases seaweed gave an increased, and in some a decreased, balance compared with the controls.

Seaweed feeding altered the intake of nitrogen in all experiments, but these changes were insufficient to account for the changes in retention. The lowered retention appears to be, in part, associated with lowered egg production and the balance data tend to support this. Losses

Table X

Nitrogen retention and balance (mg.). Bird-day means

Period	Expt. 1		Expt. 2		Expt. 3	
	Retention	Balance	Retention	Balance	Retention	Balance
C1	803	+ 15	677	+ 28	820	− 10
S2	657	− 12	506	+ 20	748	− 40
C3	659	− 8	561	+ 16	793	+ 17
S4	513	+ 93	356	+ 18	630	+ 30
C5	564	+ 11	213	− 90	751	+ 62
$S2 - C_{13}$	− 74*	− 16 N.S.	− 113 N.S.	− 2 N.S.	− 59 N.S.	− 44 N.S.
$S4 - C_{35}$	− 99**	+ 91 N.S.	− 31 N.S.	+ 55 N.S.	− 142*	− 10 N.S.

of feathers in some instances may cloud the issue but, as with calcium, there appears to be a relation between retention of nitrogen and nitrogen in the egg.

Egg composition

It is evident from Table XI that, with the exception of one result, the feeding of none of the three seaweeds at either level of intake had any significant effect on the percentage of calcium, phosphorus, chloride and nitrogen in the egg content. Further, only in the case of chloride were the changes always in the same direction. With chloride, the content in every case showed a greater percentage when seaweed was fed, and in one, but only one, case was it significant.

Table XI

Percentage calcium, phosphorus, chloride and nitrogen in egg content and percentage calcium, phosphorus and chloride in nitrogen-free shell

Period	Egg content				Shell		
	Ca	P	Cl	N	Ca	P	Cl
Expt. 1							
C1	0·061	0·193	0·184	1·84	38·4	0·176	0·074
S2	0·057	0·192	0·192	1·87	38·4	0·168	0·074
C3	0·057	0·186	0·189	1·84	38·4	0·166	0·071
S4	0·059	0·182	0·201	1·86	38·4	0·157	0·088
C5	0·056	0·188	0·190	1·87	38·3	0·153	0·065
$S2 - C_{13}$	−0·002 N.S.	+0·003 N.S.	+0·006 N.S.	+0·03 N.S.	0·0 N.S.	−0·003 N.S.	+0·002 N.S.
$S4 - C_{35}$	+0·003 N.S.	−0·005 N.S.	+0·012**	+0·01 N.S.	+0·1 N.S.	−0·003 N.S.	+0·020*
Expt. 2							
C1	0·052	0·215	0·192	1·88	38·3	0·166	0·064
S2	0·059	0·214	0·198	1·88	38·4	0·164	0·076
C3	0·058	0·212	0·188	1·91	38·3	0·164	0·063
S4	0·056	0·211	0·210	1·82	38·3	0·166	0·085
C5	0·055	0·201	0·221	1·83	38·2	0·161	0·072
$S2 - C_{13}$	+0·004 N.S.	+0·001 N.S.	+0·008 N.S.	−0·02 N.S.	+0·1 N.S.	−0·001 N.S.	+0·013 N.S.
$S4 - C_{35}$	−0·001 N.S.	+0·004 N.S.	+0·006 N.S.	−0·05 N.S.	+0·1 N.S.	+0·004 N.S.	+0·018 N.S.
Expt. 3							
C1	0·061	0·214	0·179	1·96	38·4	0·149	0·043
S2	0·061	0·208	0·179	1·97	38·3	0·154	0·042
C3	0·062	0·205	0·174	1·96	38·3	0·159	0·036
S4	0·062	0·209	0·179	1·97	38·3	0·165	0·044
C5	0·062	0·207	0·174	2·01	38·3	0·165	0·038
$S2 - C_{13}$	−0·001 N.S.	−0·002 N.S.	+0·003 N.S.	+0·01 N.S.	−0·1 N.S.	0·000 N.S.	+0·003 N.S.
$S4 - C_{35}$	0·000 N.S.	−0·003 N.S.	+0·005 N.S.	−0·02 N.S.	0·0 N.S.	+0·003 N.S.	+0·007 N.S.

A similar picture arises when the percentage composition of the nitrogen-free shell is considered. Calcium, phosphorus and chloride values show only one significant change, namely, in an increase of chloride on the 20% level of seaweed in Experiment 1. However, it should again be observed that in every case, the shell chloride did increase when seaweed was fed, and it may be caused by more adventitious chloride being picked up by the shell on its way through the cloaca when the droppings were rich in chloride.

Porosity and shell thickness

There were no significant differences in any experiment in the porosity and thickness of the shells of the eggs (Table XII).

Table XII

Shell thickness (μ) and porosity coefficients (mg. loss/sq.cm./day)

Period	Expt. 1		Expt. 2		Expt. 3	
	Thickness	Porosity	Thickness	Porosity	Thickness	Porosity
C1	307	2·41	304	2·33	337	1·74
S2	312	2·58	303	2·56	337	1·71
C3	302	2·27	307	2·72	336	1·72
S4	291	2·58	301	2·78	336	1·75
C5	315	2·45	305	2·46	333	1·56
$S2 - C_{13}$	+ 8 N.S.	+ 0·24 N.S.	− 3 N.S.	+ 0·04 N.S.	+ 1 N.S.	− 0·02 N.S.
$S4 - C_{35}$	− 18 N.S.	+ 0·22 N.S.	− 5 N.S.	+ 0·19 N.S.	+ 2 N.S.	+ 0·11 N.S.

Long-term feeding experiment

Having established certain facts by means of balance experiments it was then decided to run an experiment with more birds and for a longer time. This experiment will only be described briefly.

Group-feeding trials are not very satisfactory because there is no control of individual feeding and the interpretation of the results is not easy. The experiment was therefore planned as a randomised block using four birds (Rhode Island Red × Light Sussex) as replicates for each of four treatments. Part I of the experiment lasted 100 days during which time Group A received the control ration (150 g. of layer's mash, 6·5 g. of calcium carbonate, 0·6 g. of sodium chloride and 100 ml. of water); Group B had 15 g. of layer's mash replaced by 15 g. of *Laminaria cloustoni* (stipe), i.e., 10% seaweed. Similarly, Group C received 10% *Laminaria cloustoni* (frond) and Group D 10% of *Ascophyllum nodosum*. In Part II of the experiment the control birds received the same ration as before but the others now received 15% seaweed. The analysis of the basal ration and the three seaweeds is given in Table XIII.

Table XIII

Analysis of the dry matter of the basal ration and of the seaweed meals

	Basal ration	Seaweed meals B	Seaweed meals C	Seaweed meals D
	%	%	%	%
Crude protein	19·4	10·9	7·4	9·1
Ether extract	4·6	0·5	0·5	2·3
Crude fibre	7·1	10·3	5·7	4·0
Nitrogen-free extract	63·7	43·4	66·3	57·1
Total ash	5·2	34·9	20·1	27·5
Insoluble ash	0·4	1·0	0·9	0·5
Calcium	0·75	1·78	1·64	1·58
Phosphorus	1·03	0·27	0·17	0·15
Chloride	0·18	10·04	6·58	5·98
Moisture	11·3	10·6	11·3	12·0
Starch equivalent	65·6	—	—	—
Digestible protein	13·9	—	—	—

Seaweed meals B: *Laminaria cloustoni* (stipe)
C: *Laminaria cloustoni* (frond)
D: *Ascophyllum nodosum*

All the birds were individually fed once a day with accurately weighed quantities of food, and daily water consumption and egg production were recorded. Live-weight changes over the periods were also noted. The routine was similar to the balance experiments except that droppings and eggs were not analysed. Results are shown in Tables XIV and XVI.

The results were analysed statistically for Parts I and II of the experiment separately and the main findings were as follows:

1. The general health of the birds did not seem to be affected by feeding seaweed and there was some indication that seaweed improved palatability.

2. The control ration gave live-weight gains in both parts of the experiment, whereas *Laminaria cloustoni* (stipe) gave significant losses at both levels of feeding when compared with the control. *Laminaria cloustoni* (frond) and *Ascophyllum nodosum* did not show significant losses of live weight at the 10% level but did so at 15% (Table XIV).

3. None of the seaweed meals significantly affected egg production at either level of feeding (Table XV).

Table XIV

Live-weight changes in the individual birds (g.)

Part I: 10% seaweed

Block	Treatment A	B	C	D
1	+ 47	− 33	− 79	− 153
2	+ 141	− 113	− 81	− 1
3	+ 187	− 101	+ 125	+ 32
4	+ 214	− 161	+ 95	+ 179
Mean	+ 147	− 102	+ 15	+ 14
Difference B − A		− 249**		
C − A			− 132 N.S.	
D − A				− 133 N.S.

Part II: 15% seaweed

Block	Treatment A	B	C	D
1	+ 177	− 190	− 115	+ 9
2	+ 20	− 137	+ 48	− 258
3	+ 101	− 32	− 175	− 280
4	+ 175	+ 39	+ 1	− 180
Mean	+ 118	− 80	− 60	− 177
Difference B − A		− 198*		
C − A			− 178*	
D − A				− 295**

Table XV

Total egg production per bird

Part I: 10% seaweed

Block	Treatment A	B	C	D
1	73	64	79	69
2	76	82	85	62
3	78	81	87	77
4	71	69	74	72
Mean	75	74	81	70
Difference B − A		− 1 N.S.		
C − A			+ 6 N.S.	
D − A				− 5 N.S.

Part II: 15% seaweed

Block	Treatment A	B	C	D
1	45	42	61	48
2	67	84	63	27
3	76	70	76	73
4	74	56	68	72
Mean	66	63	67	55
Difference B − A		− 3 N.S.		
C − A			+ 1 N.S.	
D − A				− 11 N.S.

4. The greatest effect was seen in increased water consumption, which, in turn, produced very watery droppings. At the 10% level of feeding all three seaweeds caused a significant increase in water consumption over the control group, and at the 15% level this was even further increased (Table XVI).

Table XVI

Mean daily water consumption per bird (g.)

Part I: 10% seaweed

Block	Treatment A	B	C	D
1	344	431	514	386
2	371	405	434	504
3	260	474	381	381
4	312	417	450	409
Mean	322	432	452	420
Difference B − A		+ 110*		
C − A			+ 130**	
D − A				+ 98*

Part II: 15% seaweed

Block	Treatment A	B	C	D
1	410	598	604	518
2	429	533	567	464
3	305	669	592	552
4	332	582	634	681
Mean	369	596	599	554
Difference B − A		+ 227**		
C − A			+ 230**	
D − A				+ 185**

Conclusions

From the balance experiments it is apparent that none of the seaweed meals considered produced any positive results of value, although *Laminaria saccharina* showed no detrimental effects.

The chief disadvantage under the condition of these experiments seemed to be that, when *Laminaria cloustoni* or *Ascophyllum nodosum* was fed, the birds were receiving less energy than was contained in the normal ration. Thus the birds tended to lose weight or show a fall in egg production or both, depending upon the type of seaweed and the level fed. The high chloride content of all three seaweed meals caused very heavy water consumption and heavy excretion of water and chloride, but neither this nor any other factor appeared to affect the health of the birds although it cannot be ruled out that the high chloride content of the seaweed meal may have had some adverse influence on live weight and egg production.

Any changes which were observed in the calcium, phosphorus and nitrogen retention and balance could generally be explained on the basis of changes in egg production, whilst the seaweed appeared to have no effect on egg content or shell composition, or on porosity or shell thickness.

In the long-term experiment, all three seaweeds when fed at the 15% level caused live-weight losses, again probably owing to an insufficiency of energy, but at the 10% level only *Laminaria cloustoni* (stipe) caused live-weight losses. There was no obvious effect on health or egg production. However, the chloride content of the seaweeds caused considerable increases in water consumption and correspondingly watery droppings. Thus, with regard to the points where the two sets of experiments are comparable, they seem to be in very good agreement.

It may therefore be stated that 20% and 15% seaweed are too high levels for feeding, but that 10% appears to be safe, although it does not bestow any special advantage upon the ration.

It should, of course, be pointed out that our interest was chiefly in the mineral metabolism of the birds and that, under commercial conditions, these particular types of seaweed would probably not have been fed; and even if fed, they would not have been given in this way. The findings therefore refer specifically to the experimental conditions imposed.

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The Effect of the Ingestion of Marine Algae on the Thyroidal Uptake of Iodine-131

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Marine algae contain a relatively large amount of iodine. Consequently, when they are ingested in large quantities, it is quite conceivable that the thyroidal uptake of radioiodine would be lowered. However, there have been no reports of investigations concerning the degree of suppression of I-131 uptake with respect to the type and amount of algae ingested and the period of ingestion, or the recovery of uptake after suppression when algae ingestion is terminated. At any rate, marine algae such as Laminaria japonica [tangle], Undaria pinnatifida [Wakame], and Porphyridia [laver] are ingested by many people in Japan as an everyday food stuff. Therefore, it seems very important to know the degree of the effect on thyroidal uptake of I-131 by these food stuffs in order to determine I-131 uptake.

The authors carried out some investigations concerning this point and the results are reported here.

Research Method

According to Iwata[1)], the iodine content of dried samples of marine algae ranges from 0.17-0.55% in Laminaria, 0.02-0.11% in Undaria, and 0.004-0.04% in Porphyridia and organic compounds account for 60 to 80%. Also, according to Kimura[2)], 98-99% of the iodine is absorbed from the digestive tract when ingested.

The authors selected scraped tangles as a sample of high iodine content and baked lavers for low iodine content for the convenience of accurate administration of daily amounts to subjects. These algae were ingested by the subjects for 1 to 14 days, and the 24-hr. thyroidal uptake of I-131 was measured before and after algae ingestion. The scraped tangles contained 0.31% iodine and the baked lavers had less than a 0.03% iodine content. Furthermore, when the I-131 uptake of patients was measured, we frequently noted that markedly lower values of I-131 uptake occurred as a result of the patients' ingestion of Laminaria during the several days preceding the test. Thus, in such cases, ingestion of Laminaria by the patient was immediately stopped, and the subsequent recovery in I-131 uptake was studied by daily measurements.

For the measurement of 24-hr. thyroidal uptake of I-131, a directional scintillation counter manufactured by Kaken [the Institute of Scientific Measurements - trans.] was used at a measuring distance of 20 cm. 24 hours after oral administration of 10 microcuries of I-131. When the distance between the skin of the neck and the front of the counter was set at 20 cm., the error due to the shape of the thyroid becomes large. Consequently, reliability with respect to the absolute value is reduced. However, the value is sufficiently accurate for following the relative change in uptake by performing repeated tests on the same patient. Thus, 10 microcuries of I-131 was sufficient for one dose: these facts justify the use of this method. Furthermore, in the case of the second measurement of uptake, as the I-131 administered for the first measurement was still present in the thyroid, the remaining I-131 in the thyroid was measured immediately before oral administration of the second dose of I-131. Assuming that the I-131 measured at this time remains without being excreted at all even after 24 hours, the second uptake value was determined by subtracting the value obtained by multiplying the preadministration count by 0.92, the physical damping factor during the 24 hours, from the 24-hr. count after the second I-131 administration. Actually, thyroid hormone with I-131 is being secreted a little at a time from the thyroid. Thus, the damping factor after 24 hours is believed to be less than 0.92. However, the actual values are believed to vary in individual cases, and even when the physical damping value is used, the difference in values was considered small during the 24 hours. Thus, the calculation was done in this manner.

Experimental Results

1) The effect of the ingestion of tangles or lavers on the thyroidal uptake of I-131 in normal man

7 to 15 g of scraped tangles per day were ingested by 8 healthy males and 2 healthy females around 30 years of age for 1 to 14 days. The 24-hr. thyroidal uptake of I-131 was measured before and after ingestion. The results are shown in Table 1. Incidentally, 7 to 15 g of scraped tangles are equivalent to 1 to 2 bowls in soup form which is approximately the amount used in a normal diet.

Table 1 Effect of tangles on thyroidal uptake of I-131 in normal man

a	b	c	d	e [illegible]			
[illegible]	[illegible]	[illegible]	[illegible]	f [illegible]	g [illegible]	h [illegible]	i [illegible]
K.M.	♂	28才 j	16gm × 14日 k	13%	15%	0.9%	16%(20日後)
M.I.	♂	29	15 × 14	16	16	4.1	16 (12日後)
Y.F.	♀	28	14 × 14	16	16	3.8	11 (9日後)
S.I.	♂	29	12 × 14	17	21	3.6	21 (16日後)
K.S.	♂	33	12 × 14	18	20	3.5	35 (6日後)
T.I.	♂	30	7 × 14		19	0.6	17 (7日後)
H.W.	♂	29	10 × 4		18	3.1	9.2(3日後) 21.0(5日後)
T.M.	♂	27	10 × 1		14	4.2	
J.K.	♂	29	10 × 1		20	3.5	13 (3日後)
T.N.	♀	27	10 × 1		39	2.0	11 (6日後)

Table 1 notations: a: name, b: sex, c: age, d: amount of tangles, e: 24-hr. thyroidal uptake of I-131, f: one month before ingestion, g: immediately before ingestion, h: immediately after the termination of ingestion, i: recovery condition after the termination of ingestion, j: 28 years old, k: 14 days, l: --days after.

The results, shown in the table, confirm that I-131 uptake was markedly suppressed even by the ingestion of 10g of tangles only once. However, even when 15g was ingested daily for 2 weeks, uptake was found to return to the preingestion value after about 2 weeks from the termination of ingestion.

Next, 1.2 gm (3 sheets) to 3.2 gm (8 sheets) of baked lavers per day was ingested by each of 6 healthy males and 1 healthy female of about 30 years of age. The 24-hr. thyroidal uptake before and after ingestion are shown in Table 2. In other words, no effect on the thyroidal uptake of I-131 was found within the range of ingestion of lavers shown.

Table 2 Effect of laver ingestion on thyroidal uptake of I-131 in normal man

a 氏名	b 性	c 年令	d 海苔の量	e 甲状腺I131 24時間摂取率	
				f 摂食直前	g 摂食中止直後
K.S.	♂	33才 h	1.2gm × 2日 i	18%	20%
S.S.	♀	31	3.2 × 6	26	32
H.T.	♂	27	2.8 × 14	13	17
K.M.	♂	27	2.8 × 14	25	27
H.S.	♂	26	2.8 × 14	23	28
H.M.	♂	28	2.8 × 14	10	18
Y.N.	♂	25	2.8 × 14	12	11

Notations: a: name, b: sex, c: age, d: amount of laver, e: 24-hr. thyroidal uptake of I-131, f: immediately before ingestion, g: immediately after the termination of ingestion.

2) The effect of tangle ingestion on thyroidal uptake of I-131 in exophthalmic goiter patients

10 gm of scraped tangles per day was ingested for 4 to 6 days by each of 4 patients suffering from exophthalmic goiter. The results are shown in Table 3.

As shown in this table, the thyroidal uptake of I-131 markedly decreased. However, it was found that the low value gradually returned to the original uptake value by two weeks after the termination of ingestion.

3) Changes in the thyroidal uptake of I-131 in patients after the termination of long-term tangle ingestion

The 24-hr. thyroidal uptake of I-131 was measured in 5 out-patients who had been ingesting tangles for a very long period of time. As shown in Table 4, low values were observed in all cases. Thus, changes in I-131 uptake were followed after the termination of tangle ingestion by these patients.

Table 3 Effect of tangle ingestion on 24-hr. thyroidal uptake of I-131 in exophthalmic goiter patients

a 氏名	b 性	c 年令	d 昆布の量	e 甲状腺I131 24時間摂取率 f 摂食直前	g 摂食中止直後	h 摂食中止後の回復状態
T.K.	♀	50	10gm×6日 i	87%	20%	69% (7日後) 80 (14日後)
U.M.	♀	59	10 ×6	75	13	55 (7日後) j
Y.M.	♀	19	10 ×6	62	7	24 (7日後) 75 (14日後)
Y.I.	♀	22	10 ×4	79	8	33 (7日後) 79 (14日後)

Notations: a: name, b: sex, c: age, d: amount of tangle ingestion, e: 24-hr. thyroidal uptake of I-131, f: immediately before ingestion, g: immediately after the termination of ingestion, h: recovery condition after the termination of ingestion, i: days, j: --days after.

Table 4 Changes in the thyroidal uptake of I-131 after the termination of long-term tangle ingestion by patients

a 氏名	b 性	c 年令	f 病名	l 昆布の量	r 甲状腺I131 24時間摂取率 s 摂食中止直前	t 摂食中止後1週	u 摂食中止後2週	v 摂食中止後3週	w 摂食中止後4週
H.H.	♀	44才 d	g バセドウ氏病	1日20gm以上9ヶ月 m	10%	60%	70%	67%	
M.H.	♀	54	h ノイローゼ	1日20gm以上3ヶ月 n	2.4	29	30		
T.S.	♀	31	i 甲状腺腫	1日10gm以上殆ど毎日約10年間 o	8.0		22		38%
K.S.	♂	25	j 眼球突出症	1日4gm週3日約2年間 p	9.0		51		
T.T.	♂	8ヶ月 e	k 正常	1日こぶ茶1匙1杯，生後8ヶ月間 q	1.8			11.7(18日後) x	

Notations: a: name, b: sex, c: age, d: years old, e: 8 months, f: disease, g: exophthalmic goiter, h: neurosis, i: goiter, j: exophthalmos, k: normal, l: amount of tangle ingestion, m: more than 20 gm/day for 9 months, n: more than 20 gm/day for 3 months, o: more than 10 gm/day almost every day for 10 years, p: 4 gm/day, 3 days/week, for approx. 2 years, q: a teaspoonful of seaweed drink per day for 8 months after birth, r: 24-hr. thyroidal uptake of I-131, s: immediately before the termination of ingestion, t: 1 week after the termination of ingestion, u: 2 weeks after the termination of ingestion, v: 3 weeks after the termination of ingestion, w: 4 weeks after the termination of ingestion, x: 18 days after.

Due to the various circumstances of the patients, it was not possible to follow the changes for a sufficiently long period. However, from the above results, it was found that the thyroidal uptake of I-131 recovered considerably after two weeks.

Discussion

According to Beierwaltes, et al.[3], ingestion of over 1 mg of inorganic iodine has the capability of lowering the thyroidal uptake of I-131. Kohn, et al.[4] also observed a decrease in thyroidal uptake of I-131 in normal subjects after the administration of two vitamin tablets containing 0.5 mg of inorganic iodine per table for 5-9 days. It appears that the thyroidal uptake of I-131 can be lowered by a smaller amount of inorganic iodine in patients with hyperthyroidism than in subjects with a normal thyroidal function[5)6)]. According to Childs, et al.[7], this amount is 0.1 mg or more. The scraped tangles administered by the authors contained 0.31% iodine. If we estimate that 20% of it is inorganic iodine, the ingestion of 10 g of scraped tangles would mean that 10 g x 0.0031 x 0.2 = 6.2 mg of inorganic iodine and 10 g x 0.0031 x 0.8 = 24.8 mg of organic iodine are being ingested. The metabolism of the organic iodine contained in marine algae within the body is unknown. However, it is conceivable that some parts of it are converted to inorganic iodine. Consequently, the ingestion of 10 g of tangles may result in the ingestion of more than 6.2 mg of inorganic iodine. Thus, it is considered only natural that the thyroidal uptake of I-131 is suppressed. On the other hand, in the case of ingesting 8 sheets (3.2 g) of baked lavers, the total iodine content is less than 3.2 x 0.0003 = 0.96 mg calculating the inorganic iodine content and assuming that all of the organic iodine is converted to inorganic iodine. This is probably why no effect was found in the thyroidal uptake of I-131 in normal subjects. However, in the case of patients with hyperthyroidism, there is a possibility that the thyroidal uptake of I-131 may be suppressed even by the ingestion of lavers at this low level. In Japan where such marine algae are used in the daily diet, it seems necessary to pay special attention to this point in testing the thyroidal uptake of I-131. There are reports stating that the 24-hr. thyroidal uptake of I-131 is frequently 5% or at times 1% in normal subjects in Japan. It is suspected that among these reports there may be some cases where the low values were due to the ingestion of seaweeds during the 1-2 weeks prior to the tests. Incidentally, the results of tests of 64 normal subjects where the measurements were made with special attention to this point, the values varied from 9.3 to 42.5%.

In addition, regarding the number of days in which the effect of ingestion of seaweeds remains after the termination of ingestion, the results are probably influenced by the amount and period of ingestion, and the reactivity of the patient. We were unable to investigate this point fully in this study. However, based on the above-mentioned results, it is believed that even though a very large amount is ingested for a fairly long period of time, the I-131 uptake value recovers considerably in the two weeks after the termination of ingestion. Especially, even in the T.S. case where 10 g of tangles per day was ingested almost every day for 10 years, the thyroidal uptake of I-131 recovered to 38% 4 weeks after the termination of ingestion. It can be said that this indicates that even the effect resulting from long-term ingestion disappears in a relatively short period of time after the termination of ingestion.

Conclusions

1. The effect on thyroidal uptake of I-131 due to the ingestion of marine algae was studied.

2. 7-16 g of scraped tangles per day (0.31% iodine content) were ingested by 10 normal subjects for 1-14 days. As a result, a marked decrease in the 24-hr. thyroidal uptake of I-131 was observed in all cases. This low value was found to recover to the pre-ingestion value in the two weeks after the termination of ingestion.

3. When 1.2 g (3 sheets) to 3.2 g (8 sheets) of baked lavers per day (less than 0.03% iodine content) were ingested by 7 normal subjects for 2-14 days, no effect on the thyroidal uptake of I-131 was found.

4. When 10 g of scraped tangles per day were ingested by 4 patients with exophthalmic goiter, the thyroidal uptake of I-131 was markedly suppressed in all cases. It was found, however, that the uptake returned almost to the pre-ingestion value in the two weeks after the termination of ingestion.

5. In the 5 cases of patients who reported a long-term ingestion of tangles, and demonstrated low thyroidal uptake of I-131, the low values were found to recover considerably during the two-week period after the termination of ingestion.

6. Based on the above results, it seems necessary to pay special attention to this point in testing the thyroidal uptake of I-131 in Japan where such seaweeds are used in the daily diet.

In closing, we would like to express our deep gratitude to Professor Okinaka for his guidance in this study and revision of the article. We are also grateful to Dr. Iwao of the National Institute of Nutrition who kindly measured the iodine content of marine algae. Also, we are indebted to the members of the Department and the research assistants who assisted us as study subjects.

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HOW WE CAN UTILIZE OUR SEAWEED MASSES FOR FODDER

Gulbrand Lunde

The utilization of algae has assumed in the last year a role not insignificant for fishermen. Algae was burned to ash, a part of which was exported and a part used here in our country. For this purpose algal ash production used, for the most part, a floating algae which was brought in large masses from the beach and burned. The price of seaweed ash was so good that it paid for itself to cut the algae, which was then dried and burned to ash. The export of algal ash in 1932 was nearly 5000 tons, and the value of iodine- and algal-ash export in the same year amounted to 1,370,000 crowns (about $195,714). After the price of iodine fell and with it as well the price of algal ash, this industry was profitless and fell off. It was also necessary to find compensation for the coastal population for this loss, so an investigation of the utilization of seaweed and algae was begun.

The studies have covered both attempts which aimed at utilizing the seaweed industry and those on how seaweed and algae could be better used as fodder.

Seaweed and algae have been used as fodder and are needed even today as an auxiliary feed in various places along the coast. In relation to this, observe the name pig seaweed. Seaweed is sliced and soaked with warm water to remove part of the mineral salts before giving it to the animals. This is called deadening the seaweed. That quantities of seaweed in the fodder have a good effect was known early in Norway.

Tek. Ukeblad 86:549-53. 1939.

Our most important seaweed and algal species

We classify seaweed species into three main groups: green algae, red algae, and brown algae. Only brown algae are found in such great quantities that we can speak of gathering them in large amount as fodder. We shall therefore speak here only of brown algae. Brown algae can be divided into two main groups: algal species and seaweed species. Of these seaweed grows in shallow water and a large part stays dry therefore at low tide. The most important seaweed species which would have practical significance as fodder material is Fucus serratus which people also commonly call saw seaweed, as well as Fucus vesiculosis or bubble seaweed. There is also Ascophyllum nodosum which is also called pig or bud seaweed. All these seaweed species are perennial. The new leaves grow from the top of the old stem, which in this manner gradually becomes longer and longer. Of these seaweed species the saw and pig seaweeds have been used as fodder more than the others. The bubble seaweed contains matter which affects weight reduction.

Algal species grow in deeper water. The most important ones are Laminaria digitata or finger algae and Laminaria cloustoni, which is called great algae. Algae species are several meters long. They grow in deep water and often stand like a whole forest beyond the coast. The leaves are annual. They grow from the top of the stalk in the winter and shove the old leaves in front of them. The old leaves gradually wither and fall in the spring of the year.

Another important algal species is <u>Laminaria saccharina</u>, which is also more than a meter long and looks like a pleated leaf. This alga is usually called sugar alga because when it dries, a white material separates out on the surface, which tastes sweet. This material is mannitol.

Finally <u>Alaria</u> may be mentioned, which is also called cattle algae. It is an annual, narrow, pleated leaf, several meters long. It begins to grow early in the winter, in November-December, grows to full size in the spring, April-May, and thereafter begins to wither. In the summer only the remnants of the stalk are left.

It is the great alga which forms the main quantity of drifting algae.

Seaweed and algae have entirely different compositions from land plants, and are consequently also entirely differently structured from the fodder material usually used. Since the large leaves of the algal species are annual, we can anticipate finding a large variation in algae composition. We also find these variations in seaweeds, but the structure of these is much more constant and varies less during the year. It is characteristic of both seaweed and algae species that the ash or mineral matter content is high. The mineral content in dried seaweed and algae is between 15 and 40 %. The rest is made up of various organic substances which are only partially identifiable. The most important and best known of these substances are algin, lamianrin, and mannitol, which are all carbohydrates. Besides these known carbohydrates are found some few types of nitrogen-free extractive matter whose composition is not known and which today we have no sure method of determining. The contents of these unknown substances is higher in seaweed species than in algae. Seaweed and algae also contain nitrogen-containing substances which we may call protein. The composition of these proteins is still unknown. Likewise seaweed contains fibers, or cellulose. This cellulose is little different from cellulose in land plants. Furthermore, seaweed contains various pigments and vitamins.

If we consider the organic materials, then algin above all characterizes the seaweed and algae species. Algin is a major ingredient in brown algae. Algin itself is insoluble in water, but some of the salts such as alkali or magnesium salt are water-soluble. Laminarin is made up of glucose in the same way as starch and it is in actuality the seaweed's starch. Laminarin is the algae's food store. Since laminarin is composed of the same basic components as starch, we must take it for granted that it is extremely valuable as a feed material. Algae are viewed therefore more valuable as fodder the higher the laminarin content is. It is of the greatest significance for a rational use of algae as a fodder that it be harvested at the proper time, when the laminarin content is highest.

Another characteristic component of algae is mannitol. Mannitol is a hexavalent alcohol which resembles varieties of sugar and tastes sweet. The mannitol content was determined by using its property of rotating polarized light in the presence of arsenite.

As has been mentioned, we find that seaweeds have a composition different from that of algae. We find above all there are no great variations in composition. The algin content is about the same as in algae. On the other hand laminarin and mannitol contents are low and comparatively steady the whole year.

It is also of interest to observe the vitamin content in seaweed and algae. Vitamin A occurs as carotene. Carotene content is about 100 mg/kg. We have also determined the content of B-vitamins in seaweed species. In the algal genera Fucus and Ascophyllum, carotene content is higher, up to 300 mg/kg. We have also determined the content of B-vitamins in seaweed species. In Laminaria saccharina and Alaria we found about 60-75 I.U. vitamin B_1 per 100 g fresh seaweed, which corresponds to 3000-4000 I.U. per kg dried . In other seaweeds the content was somewhat lower. The vitamin B_2 (riboflavin) content in Laminaria was 6-10 mg per kg dried laminaria. In other algae we found a higher value. Vitamin C content was just the same both chemically and biologically. Fucus species contained the most vitamin C, about 20-60 mg/100 g, but we have found values even more than 100 mg. Vitamin C content in these seaweed species is consequently about the same as apple juice. We have also investigated the extent of vitamin D content in seaweeds, but it is known that the quantity in this case is so small that it has no significance. It is still possible that seaweeds may contain provitamin D. Studies of this are in progress.

It is the particular content of carotene and riboflavin in seaweed that has significance. These vitamins are the most stable. One can calculate that vitamin B_1 is in part destroyed in drying the seaweed and that vitamin C content is just as greatly reduced. Vitamin C content therefore has little importance for domestic animals.

Digestibility of algae and organic components in seaweed

Seaweed and algae meal are recommended as additions to feed concentrate mixtures and it is reported in most accounts that the least addition of seaweed meal has a favorable effect in varying proportions. What is however of prime interest to us is to see what value the organic matter has in algae as fodder. Algae meal itself is only added to fodder in minor amounts; it will nevertheless be of significance to see how large a fodder value can be calculated. Algae and seaweed meals have so widely differing a composition from ordinary fodder substances, that one can assume that the fodder value cannot be calculated in the usual manner. The most important question is to investigate whether the organic matter in seaweed can on the whole be digested or used by organisms. This question can hardly be solved by practical experiment. However there is the great difficulty that in such an experiment, one may give the experimental animals a comparatively large amount of seaweed meal in the feed. Since the meal has so high a mineral content, and in particluar, a high iodine content, one can expect that it would act to disturb the organism and thereby give deceptive results to the study. On the other hand seaweed meal, is in its composition and structure so different from the fodder animals are accustomed to, that one can expect that it may take a comparatively long adaptation period for the algae fodder to be utilized as much as possible. A study examined horses in France and the study which we undertook has confirmed this.

However in order to obtain an overview of this question, we have chosen to study digestibility of each single component in seaweed meal, and we have attempted to separate them as far as possible from the other disturbing elements. First to be considered here are digestibility studies on algin. As experimental animals black and white rats were used. The studies showed that the degree of algin digestion rose during the test period from 54% to 80%. After 6 weeks the study was ended. Digestion efficiency was then 80%. It is naturally not impossible that continuing the study longer could be considered. The study showed clearly in every case that one must assume a relatively longer adaptation period, in order for the rat organism to be able to digest the algin as completely as possible. This agrees entirely with studies which were conducted by Lapique on the feeding of horses with seaweed in France, and which showed that horses after only 1-4 weeks could digest the seaweed. Whether intestinal flora play any part in digestion of algin cannot be decided until after new studies.

We cannot of course conclude directly from these studies anything about the digestibility of algin by our own domestic animals, such as swine or ruminants. But after a digestion study which was conducted by Ringen at the Norwegian Agricultural School (Norges Landbrukshøyskole), it was shown that the nitrogen-free extractive material was utilized by sheep to a large extent in every case. We may therefore conclude that a large part of the algin is digested as well. It is completely certain that this can be determined only after a digestion study for domestic animals as to whether pure algin preparations are used as much as possible, and how the large amounts of salts and other components which may cause disturbances, are removed.

Algae contains as well, in the summer, a large amount of mannitol and it is therefore of significance to see whether it can be utilized by animals. It was believed earlier that mannitol was indigestible. This was concluded in a study done by Jaffe in 1883, in which, after feeding dogs mannitol, it was found in the urine. Therefore it was also believed that mannitol could be used as a sweetening for diabetics. Later it was seen that this was not true. Tannhäuser and Mayer demonstrated in 1929 that mannitol causes glycogen accumulation in the liver. Carr was able to show that mannitol produced a weak but obvious increase in the blood sugar curve. Lecocq found that pigeons could utilize mannitol completely when the amount was 35% of an otherwise fat-rich diet. Todd, Myers, and West as well as Carr and co-workers in America showed that glycogen content in the liver of rats rose after feeding with mannitol. There is thus no doubt that when mannitol is given to rats as a part of the diet, it will in all cases be partially utilized.

We have at the Hermetic Laboratory (Hermetikklaboratoriet) conducted a digestion study on rats, in which we replaced carbohydrates in a synthetic diet mixture with different amounts of mannitol. When half the amount of the carbohydrates was replaced, corresponding to 30% of the diet, the rats became sick and died.

However in replacing 1/4 of the carbohydrates, corresponding to 15% of the diet, it was shown that the animals had practically normal growth on the diet.

There is at hand no study on the utilization of mannitol in our own domestic animals. It is nevertheless likely that ruminant organisms are adapted to a higher degree than carnivores to utilize mannitol.

Of special significance is algal content of laminarin. This material which algae contains a great deal of as a host, is built up in the same manner as starch. Upon hydrolysis it yields pure glucose. One may therefore assume that laminarin would be utilized as well as pure glucose, or 100%.

Regarding the ohter nitrogen-free extractive matter of more unknown type, there is at hand no experimental investigation on their digestibility. A study conducted by Ringen at the Norwegian Agricultural School has however shown that the digestibility in sheep of the sum total of nitrogen-free extractive matter is extremely high.

With regard to seaweed's and algae's fibrous matter, we can also draw certain conclusions concerning digestibility from the preceding studies. Fibrous matter is composed similarly to cellulose in land plants, but it is probably more easily digested than land plant cellulose. It is presumed to be closer to a kind of semi-cellulose. Gloess believes that the fibrous matter in algae is more easily digestible than that in seaweed species. This is also certainly correct, since while algae blades are annual, seaweed is perennial and gradually becomes more tree-like. That algae's fibrous matter is easily digested was also established in a study conducted by the French Veterinary Board. Upon feeding horses it was found in the beginning that partly whole algae pieces were in the feces, but in a short time these pieces disappeared entirely, which shows that horses, after a short adaptation period, were able to break up the algae pieces.

The protein content in seaweed and algae is not especially high. In algae it is highest in the spring, but since algae for fodder should be harvested in the fall, the protein content plays an especially small role.

Seaweed and algae also contain a minor amount of ether-soluble components which we have called "fats". There is no study of the composition of this fat. It is also difficult to determine whether it can be utilized by the organism. Ringen has found, in his digestion study on seaweed and algae in sheep, that this fat is practically completely digested.

Study in calculating the fodder value of seaweed and algae meal

We have made a study to calculate the fodder value of seaweed and algae meal, patterned after the investigations above. We are however aware that this calculation is burdened with a number of uncertain aspects, such as that one cannot produce an account which will be entirely correct. But it should nevertheless be possible to give a picture of the feed value. For laminaria we have allowed for a digestion coefficient of 100.

For protein we calculated 50% digested in algae, but protein in seaweed is indigestible. For fat we have accounted for a digestion coefficient of 100. For the other more unknown nitrogen-free extracts, which include mannitol, we calculated an average digestion coefficient of 75. We calculated 50% for fibers in algae, but the fibers in seaweed are considered indigestible. These digestion coefficients should in every case not give a very favorable picture of digestibility. As a substitution number for carbohydrates we calculated 1, for protein 0.94, and for fat 1.9. The values were calculated according to Edin's formula. From these numbers we calculated NK_F and other units per 100 kg. These are for meal from autumn algae with 10% water - 70 units, for spring algae 49, and for Ascophyllum 53. These numbers correspond to those for seaweed and spring algae which Ringen calculated after his digestion study with seaweed and algae meal in sheep. Unfortunately only the usual feed analysis was carried out for seaweed meal in Ringen's study. It would have been of great interest to have determined the laminarin and algin contents. It is indeed, as we have seen, by far of the most significance for feed value.

Of the greatest interest is it to note the large difference which we find in feed value in fall and spring algae. A comparison with others indicates that seaweed meal and spring algae have about the same feed value, which is high enough, but meal from autumn algae is considerably better. It is of course assumed that the amount of seaweed meal in the feed will not be so large that disturbances in digestion will occur due to the mineral content.

At the Hermetic Laboratory we conducted a series of fodder studies to find out if additions of small amounts of algae meal have any effect. In the first studies we used rats as the experimental animals. The studies showed that with an addition of 10% laminaria, the rat utilized the fodder about 10% better. From the studies it also turned out that we were able to replace 10% corn meal and 8½% potato meal, and practically pure starch, with 20% algae meal, without the fodder being reduced. It may naturally be strongly emphasized that this study was conducted with rats, and that the relationships cannot be applied to domestic animals without further data.

In a new fodder study conducted in the same way, we replaced 10% hay meal with 10% algae meal, and in another study 20% hay meal with 20% desalted algae meal "Algit D2" or 20% desalted seaweed meal, Ascophyllum.

These feed studies indicated a suitably encouraging result, such that we decided to make a study with addition of seaweed meal to fodder for pigs raised for market. The study was set up as far as possible as feeding is done in practice, in that the animals made up a part of the stock at a large stock farm at Jaeren. The study involved 48 swine which remained in the study until their weight increased from 15 to 60 kg. We sought as far as possible to choose a feed composition which lay as close as possible to that usually used at the swine farm. Whey made up an important part of the fodder. However we were afraid that the large whey mixture would surely obscure the effects of seaweed meal; we divided the swine into four groups which were as alike as possible, in that we took account of the weight sought in the period of a week. Each group of 12 swine went together in one yard. One of the groups received the usual pigfeed with whey; in another group a part of this swine fodder was replaced with 5.7% seaweed meal. The two other groups received no whey, and in one of these 5.7% was replaced with seaweed meal. Each animal was weighed at the beginning of each week, and thereafter every third week until they had an average weight of 60 kg. The amount of feed consumed in each group was also accurately controlled. The study shows that the swine which had received whey grew considerably faster than those which went without. The swine which received whey reached market weight about a month before the other groups. There is little difference in the weight curves for the two groups which received whey. The seaweed group was a little worse. There is a big difference between weight curves in groups without whey, where the seaweed group's animals fared better. The animals in the whey group ate a considerably larger amount of feed, such that the number of units per kg increase was about the same in all the groups. There was indicated a small difference in the whey groups, which shows that utilization is slightly better without seaweed addition. In the group without whey, the relationships are reversed. Here the fodder utilization is better in the seaweed group. It should also be noted that digestion is entirely normal, and not noted in any case were looser bowels in the animals which received seaweed meal in the feed. All the swine were slaughtered and exported. It has not been demonstrated that there was anything wrong with the meat which can be ascribed to seaweed meal feed. The study shows that you can in practice add 6% seaweed meal to swine feed to advantage. The feed utilization is not worse in the seaweed group than in the other groups. We should also note that we used in this study seaweed meal, as in the earlier studies with rats and the study which was conducted by Ringen at the Norwegian Agricultrual School, which is not as good as algae meal. Comparable studies should be repeated with algae meal of varying quality.

The feed study with addition of seaweed and algae meal to swine feed was conducted also by Ringen at the Norwegian Agricultural School. In these studies we used 5, 10, and 20% in feed concentrate of the seaweed meal "Neptune", represented by Ascophyllum, and another study was made with an algae meal "Algit", maufactured by Algea Products A/S. The studies show that addition of 5% seaweed meal yields one of the best growth rates per animal per day. There was however a decrease in marketable percentage in the groups which had received seaweed meal, so that this relationship was partially equalized. Mr. Ringen has also conducted some interesting weight studies. The study concerned how large an amount of seaweed and algae meal the pigs could tolerate. The animals received up to 830 g seaweed meal per day. The seaweed meal increased the appetite, but when it reached the amount of 450 g/animal per day, the pigs began to have a little loose excrement. Then the amount was increased to 830 g/day. In spite of these large amounts of seaweed meal, growth in the seaweed meal group was not essentially worse than in the control group. There is not anything notable in that the animals became worse with the large addition of mineral matter and iodine which they received.

There is available also an interesting study which was conducted in France in 1920 on horse feed with seaweed meal. In the studies a weight portion of oats was replaced with a weight portion of raw algin, and the algae preparation was washed out with hydrochloric acid. The study showed that the horses which received algae grew better than those which got oats. The horses were also restored to health which had lymph conditions. Because of Prof. Lapique, a study was conducted in the French Army with an algae meal which was washed with milk of calcium. Here also 1 kg oats was replaced with 1 kg algae meal. In the conclusion of this study it is said that algae meal could replace oats in the ration of military horses. Oats could be fully replaced with algae meal when the horses were worked moderately. Even with hard work, such as on 3-day maneuvers, the algae could entirely replace oats without any injury to the animals.

There is also available a recent account from the veterinary inspector, Maj. Moholdt, concerning a feed study on military horses at Gardermoen in the summer. The horses were divided into three groups with 10 in each group. In group 2, 1 kg oats/day was replaced with 1½ kg "Algit" algae meal and in group 3, 2 kg oats were replaced with 3 kg "Algit". The study lasted 2 months. The animals were weighed in the study. The algae feed had no effect on the horses' weight. From the study it turned out that "Algit" could replace oats for military horses in the relationships which were stated. The amount would nevertheless not exceed 2 kg per animal per day, since the horses otherwise would have loose bowels. There could not be pointed out anything abnormal in the study horses which received more than 3 kg/day. No damaging influence was noted on the whole. The horses behaved normally and there could be demonstrated no difference in work performance between the study horses and the control horses. There was, however, an observation made which is of great interest. The control horses and horses in the control group were studied for tapeworms. This investigation was conducted by veterinary lieutenant Aarflott. It was shown that the horses which were fed with seaweed meal had considerably fewer tapeworm eggs than the control horses. This was said about it in the veterinary inspector's report, in addition: "Tapeworms are extremely widespread among our horses and other domestic animals. A serious worm infestation reduces the animal's condition to a considerable degree. It has been shown to be most usual to treat horses for worms. Should it be confirmed in a later study that seaweed is able to reduce worms to a considerable degree, it would be an important factor in keeping horses in condition." In this study 1 kg oats was accordingly replaced with 1½ kg "Algit" seaweed meal. We set the number of feed units in oats at 84, so we determined that seaweed had a feed value of 56 units. This figure accordingly lies right in the middle between the figure calculated by us for number of feed units in algae meal from autumn and spring. To use the autumn algae, one can in this manner calculate that the amount of algae meal which should replace 1 [illegible] oats will be considerably less.

As it turned out from the various investigations, seaweed has a feed value in the best case of about 70 units, and in the most unfavorable case about 50. The feed value should, according to this, lie between oats and good hay. Seaweed and algae cannot be designated as a feed concentrate, as in some quarters it has been recommended. The importance of seaweed and algae meal lies not chiefly in its feed value, but in its mineral salt content. One can therefore not regard seaweed and algae meals' feed value only from the number of the feed unit which it represents. It supplies the organism as well with a pure salt of which perhaps its greatest importance is its iodine content. That iodine in small

ts is undoubtedly necessary for the organism is not in question. It is necessary for building up the thyroid hormone. With an iodine deficiency in nutrition, abnormal changes appear in the thyroid gland, which are called goiter. This illness is widespread both among men and domestic animals in a purely inland district in our own country as well. It is accordingly here in Norway's districts also, where iodine supply in domestic animal nutrition is too little. The most natural and cheapest means is to add seaweed or algae ash to the feed. Iodine is said also to have a favorable effect on various domestic animal diseases. Holmboe reprted that sheep which walked on the beach and ate seaweed and algae were less afflicted by lung inflammation in spring than sheep which had not gotten algae. Also chickens let loose on the beach were affected in the manner of Holmboe's favorable experience with algae. At the Spörck-Haslund chicken farm this relationship was confirmed. According to a thousand-year-old tradition, seaweed products are used in Japan and China for various diseases, including tuberculosis. In this connection I will mention the study which was made in France on horses, which showed that seaweed fodder cured lymph conditions, and the studies which were conducted with seaweed feed on horses in Norway by Veterinary Inspector Noholdt, in which it was demonstrated that seaweed feed was effective against worms. It can also have a great significance for birth mortality, which in certain parts of the country is comparatively high. On the whole it is seen that seaweed and algae and their preparations favorably influence the organism's resistance against infectious diseases. In France Plaizot and Lissot did a study with domestic animals over a period of three years, and found that a supply of algal salts yielded a general improvement in the state of health and weight of the animals. This means that the organism's loss of iodine is larger during pregnancy and infectious diseases, and that the increased amount of iodine which animals get in algae salts affects this favorable relationship.

It can also be mentioned that the amounts of iodine which are added to the feed in the form of seaweed or by another means ought not to exceed a certain amount, since it can otherwise lead to abnormal conditions in animals which are called iodism. This was also shown by Ringen at the Norwegian Agricultrual School in feeding pregnant swine with extremely large amounts of seaweed meal. The relationship makes it desirable for the manufacture and use of seaweed and algae meal to be under adequate control. Seaweed and algae meal which are manufactured and sold ought to be of a uniform quality. With the sale of algae meal, it would clearly result in a question of spring-harvested goods which is, accordingly, rich in mineral matter and iodine, its feed value is comparatively small, or if it is a question of algae gathered in autumn, which has a higher feed value in return for a smaller content of mineral matter and iodine. The amount of seaweed and algae meal in feed concentrate ought to lie between 5 and 10%. If it goes higher than 10%, the mineral matter content ought to be decreased with washing. There is such washed seaweed and algae meal on the market. One can without danger use a larger amount of this than of untreated products.

A question which naturally arises is how larger are the amounts of seaweed and algae which one cane harvest yearly along the Norwegian coast without the seaweed amounts being dpeleted. It is obviously extremely difficult to give an answer to such a question as this. The seaweed masses along the Norwegian coast are enormous. Only someone who has traveled along the coast can form a picture of what scale the masses we are concerned with here are. With ebb tide an enormous belt of seaweed can be seen along the entire coast; especially is it observed in Finnmark, where the difference between ebb and flow is great. Here even large masses of laminaria come to view when the sea is out.

One can get a closer picture of the seaweed masses' size by looking at the drift algae which each year are cast on land at different places on the coast. Thus the production of algae ash was at its highest when exports were close to 5000 tons/year. This should, with an ash content of

25% of the dry material, answer for ca. 20,000 tons of dry algae or ca. 125,000 tons of fresh. After Steffensen's calculations, one can estimate that the coastline where drift is gathered was ca. 200 km long. He further calculates that if a corresponding amount were harvested along the whole coast, this would answer for at least 375,000 tons of dry seaweed/year. Drift is made up only of algae or the large laminaria species. In addition to this are the seaweed Ascophyllum and Fucus species. At Nordmøre, on a comparatively limited coastline, ca. 10,000 tons dried seaweed/year of these seaweed species were gathered. For the whole country the amount which one can gather can be set at at least 300,000 tons. This figure is obviously extremely uncertain, but it is sure not to be too high and it is very possible that it can be doubled. We calculate that 1/10 of this amount is collected, with a direct price to the gatherers of 4 øre (about 0.057 cents)/kg for dried algae and 2 øre for seaweed, so this represents a sum of 21 million crowns (about $3 million) direct price to the gatherers.

We summarize what was said above on the use of seaweed and algae meal as feed; accordingly one may say that the question can be seen to be nowhere nearly solved. The different effects which were established by adding seaweed and algae meal ought to be conifrmed by further studies and we hope that in this area it may result in a fruitful cooperation between the Agricultural School, the Veterinary School, and the Hermetic Laboratory. In any case one can conclude from the above that a smaller amount of seaweed and algae meal in feed has a favorable effect and therefore ought to be recommended. There is a question also of the greatest national economic significance both because seaweed and algae meals are a wholly Norwegian product and because this industry can provide subsistence for large parts of the coastal population; these questions are difficult to separate.

Discussion

Prof. Breirem of the Norwegian Agricultrual School complimented the lecturer for the account of his research, but believed him too optimistic on the question. At the Agricultrual School people have had long experience with seaweed meal feed, but the experiences were not extremely favorable, and this indicated that animals were not willing to eat the feed. The work by the agricultrual consultant Ringen on seaweed meal was one of the most worthwhile ones done on Norwegian feed preparations. The seaweed meal has a feed value which can be paid with up to 10 øre (about 0.14 cents)/kg, while 16 øre is being asked; and as far as mineral salts are concerned, seaweed meal is very high in them when its iodine content is considered. As an iodine source the figures mentioned for seaweed meal indicate that it could be worth recommending in mountain communities where there is often an iodine deficiency. Seaweed meal's vitamin content was not given any further consideration by the people at the Agricultrual School. What is at present most interesting is if seaweed meal may be significant as a replacement feed in a crisis like the present one. Prof. Breirem believed however that the cellulose in the feed was soluble.

Manager Torgersen of the Algea factory explained more closely the collection of seaweed for his establishment. This year 7000 tons were gathered and he pointed out that this meant a significant income for the district, with a corresponding saving for the State in the form of relief payments, etc. There was already developed an export market and the figures meant that quality control was necessary.

The figures were worthwhile for the studies which were conducted at the Agricultrual School, but could not eliminate the feeling that people had come too early to a conclusion. Research studies ought to be connected with assistance from veterinarians in order for them to be completely correct, and the results must be given an absolutely objective form.

Manager Gulbrandsen was in agreement with Torgersen's comments. The Agricultural School has brought out a newspaper article which has injured our seaweed meal export. It is not stated in it that the information given is incorrect, but the Agricultural School has confined itself to feed value, while there are also other values which are necessary to consider.

Dr. Finn Batt emphasized that it was a known phenomenon that with a high iodine supply, one obtains an enlarged thyroid gland. It is with small doses that treatment of goiter may be undertaken, and this may occur mainly by eating fish. If one wanted to supply stock, milk, or eggs with an adequate iodine supply by putting seaweed meal in feed concentrate, the doctors would be grateful, and the speaker concluded that it will mean a great deal for folk health on the whole in obtaining more iodine.

The consultant Dr. Spildo raised the question of whether, in a iodine-containing fertilizer, it does not cause people and animals to be supplied with the necessary amount of iodine in as easy a manner as with more direct methods.

The lecturer Dr. Lunde emphasized that it was a fact that people all over the country had observed good results in the use of small amounts of seaweed and algae for domestic animals, but there had also unfortunately occurred cases of using too large an amount. Seaweed meal's value as feed cannot be evaluated only from the difference in feed units it contains. The content of salts, especially iodine, as well as of vitamins, also plays a large role. Seaweed meal is also thought to have a favorable effect on resistance of animals to certain illnesses and is thought to be effective against intestinal parasites. All these questions cannot be said to be ultimately solved and the lecturer again expressed the hope that a fruitful cooperation may come about between the Norwegian Agricultural School, the Veterinary School, and the Hermetic Laboratory to solve these problems which are so important for the country.

The chairman, Prof. Schieldrop, ended the discussion, expressing the observation that the opinions on seaweed's use as feed reveal strong contradictory evidence, and it probably take some time in studies in order to draw the correct conclusions. But this can perhaps be seen from a narrower point of view, in light of the situation we are now in, and it is thought that seaweed opponents stand on a more common ground. The question is of not being able to find a basis for a cooperation leading to directives which would be a significant value for us now.

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[illegible] SEAWEED [illegible] LAYING HEN[1]

F. M. [illegible]cIntyre[2]

[illegible], Kappan, N.S.

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[illegible]STRACT

[illegible] studies were carried out with laying hens on two species of [illegible] *[illegible]* and *Ascophyllum* [illegible], the [illegible] dominant on the Nova Scotia coast. [illegible] by the laying hen. In [illegible] meal to the basal ration depressed the digestibility of [illegible] except fat.

[illegible] state, and as a meal when dried and [illegible] and poultry, has been under study for many [illegible]. However, there is still some doubt as to the nutritive value of [illegible] in spite of the existence of a fair volume of published material on [illegible] (4, 5, 6, 13, 14, 15). This lack of knowledge is due partly to the fact that few well controlled digestibility trials have been carried out. Until very recently there was also a lack of appreciation of the large number of seaweed species available, the variations in chemical composition from species to species and the considerable seasonal variations within species.

Work to date has shown that seaweed cannot be regarded as a basic food. The value of seaweed meal is to be assessed, therefore, on the basis of its value as a supplementary feed, particularly its value as a source of minerals, vitamins, and available carbohydrates. Numerous feeding trials have shown that from 5 to 10 per cent of seaweed meal can be safely added to the diet of farm animals and poultry (1). Greater proportions frequently result in disturbed metabolism and very moist excrement.

A number of trials (12, 14, 15) have shown the digestibility of seaweed to be greater for ruminants than for swine. There is also some evidence that seaweed meal has a favourable effect on the nutritive value of the basic ration with which it is fed, although the reverse effect has also been noted, and in some cases a negative digestibility has been observed for protein (12, 15).

The object of the work reported herein was to study the digestibility, for poultry, of seaweed meal prepared from two different species of seaweed collected at different locations along the coast of Nova Scotia.

EXPERIMENTAL

The two rock weeds most abundant on the Nova Scotia coast, *Fucus vesiculosus* and *Ascophyll[illegible]m [illegible]*, were [illegible] in this study. The plants were harvested at low tide, [illegible] dried in the sun and further dried in a steam-heated dryer. The [illegible] in a [illegible] mill to a fineness suitable for feeding. The species [illegible], sites and times of collection, and proximate analyses [illegible] used in this study are presented in Table 1.

[1] Contribution from Poultry Division, [illegible] Farm [illegible], Canada Department of Agriculture.
[2] [illegible]

TABLE 1.—SPECIES, SITES AND TIMES OF COLLECTION, AND PROXIMATE ANALYSES OF SEAWEED MEALS USED IN DIGESTIBILITY TRIALS

Species of seaweed	Site and time of collection	Moisture	Crude protein	Ether extract	Crude fibre	Ash	Nitrogen-free extract	Organic matter
		%	%	%	%	%	%	%
Mixed*	Near Digby, N.S., Oct., 1949	18.2	7.7	1.3	9.7	26.2	36.8	55.6
Ascophyllum nodosum	Hackett's Cove, May, 1953	12.8	3.9	5.6	3.3	16.5	57.9	70.7
Fucus vesiculosus	Herring Cove, May, 1953	12.8	12.1	3.6	4.4	17.4	49.7	69.9
Ascophyllum nodosum	Port Lorne, June, 1953	10.2	8.0	0.8	4.9	15.6	60.5	74.2
Fucus vesiculosus	Port Lorne, June, 1953	8.5	9.4	1.2	5.1	19.2	56.6	72.3

* Mostly *Ascophyllum nodosum* and *Fucus vesiculosus.*

The birds would not eat the seaweed meal when it was offered as the sole food. Accordingly, the meal was fed in admixture with a basal ration the digestibility of which had been previously determined. The ratio of basal ration to seaweed meal fed in each trial and the proximate analysis of each ration are shown in Table 2.

Seven trials were carried out with seaweed meal over a period of three years (1952-1954).

Six Barred Plymouth Rock laying hens, approximately one year old, were used on each trial. The birds were kept in individual metabolism cages similar to those described by Olsson and Kihlen (8). The experimental feeding period lasted 4 to 8 days and was preceded by a preliminary feeding period of 4 days. In the trials conducted in 1952 the feed was offered in the form of a dry mash and was kept before the birds from 9.00 a.m. until 4.00 p.m. Daily feed consumption was recorded by weighing back the unconsumed portion at the end of each day. In all other trials the feed was mixed with water and fed twice daily in the form of a moist mash in amounts which the birds would readily consume. Water was provided *ad libitum.* The duration of the trials and the average feed consumption per bird are shown in Table 3.

The excrement was collected on anodized aluminum trays placed under the metabolism cages. The excrement from each bird was collected daily at 8.00 a.m. and dried in an electrically heated oven at 80° C. At the termination of each trial, the total excrement from each bird was ground, mixed and sampled for analysis.

The feed and dried excrement were analysed for moisture, total nitrogen, ether extract, crude fibre and ash, by standard methods (7). The crude fecal nitrogen, as opposed to the urinary nitrogen, was deter-

TABLE 2.—COMPOSITIONS AND PROXIMATE ANALYSES OF RATIONS

Year	Trial number	Ration		Percentage composition of rations						
				Moisture	Crude protein	Ether extract	Crude fibre	Ash	Nitrogen-free extract	Organic matter
1952	1	Basal (1)		12.2	14.2	1.9	6.4	6.6	58.7	81.2
	2	70% Basal + 30% Seaweed Meal	(*a*)	14.0	12.3	1.7	7.3	12.5	52.2	73.5
1953	3	Basal (1)		12.5	16.1	2.6	6.0	7.9	54.9	79.6
	4	70% Basal + 30% Ascophyllum	(*b*)	12.6	12.4	3.5	5.2	10.5	55.8	76.9
	5	70% Basal + 30% Fucus	(*c*)	12.6	14.9	2.9	5.5	10.7	53.4	76.7
	6	50% Basal + 50% Fucus	(*c*)	12.6	14.1	3.1	5.2	12.6	52.4	74.8
1954	7	Basal (1)		9.6	18.9	2.2	4.5	7.9	56.9	82.5
	8	70% Basal + 30% Ascophyllum	(*d*)	9.8	15.6	1.8	4.6	10.2	58.0	80.0
	9	90% Basal + 10% Fucus	(*e*)	9.5	17.9	2.1	4.5	9.1	56.9	81.4
	10	70% Basal + 30% Fucus	(*e*)	9.2	16.1	1.9	4.7	11.3	56.8	79.5

Basal ration was in all-mash ration complete in all known nutrients.

Site and time of collection of seaweed:
(*a*) Near Digby, October, 1949.
(*b*) Hackett's Cove, May, 1953.
(*c*) Herring Cove, May, 1953.
(*d*) Port Lorne, June, 1953.
(*e*) Port Lorne, June, 1953.

TABLE 3.—NUMBER OF HENS, DURATION OF COLLECTION PERIOD, AND AVERAGE FEED CONSUMPTION

Year	Trial number	Ration	Number of hens	Collection period, days[1]	Av. feed consumed, gm.
	2	70% Basal + 30% Seaweed Meal	6	4	424
1953	3	Basal	6	5	480
	4	70% Basal + 30% Ascophyllum	6	5	500
	5	70% Basal + 30% Fucus	6	5	500
	6	50% Basal + 50% Fucus	6	4	207
1954	7	Basal	6	8	800
	8	70% Basal + 30% Ascophyllum	6	7	700
	9	90% Basal + 10% Fucus	6	8	960
	10	70% Basal + 30% Fucus	6	7.	700

[1] The collection period was preceded by a preliminary feeding period of 4 days in each trial.

mined by the method outlined by Ekman, Emanuelson, and Fransson (2). The organic matter and nitrogen-free extract attributable to intestinal and urinary sources were calculated by the methods outlined by Olsson and Kihlen (8).

RESULTS AND DISCUSSIONS

The birds showed some reluctance to consume the rations containing seaweed meal when it was offered in the dry form. When the rations were moistened with water and offered as a moist mash, then the birds consumed them quite readily, with one exception. This exception was encountered in Trial 6 with the ration to which 50 per cent of seaweed meal (*F. vesiculosus*) had been added. In this trial considerable difficulty was experienced in getting the birds to consume the feed. There was no adverse effect on the taste or odour of the eggs when seaweed meal was fed.

The results of this work are summarized in Table 4. The addition of seaweed meal to the basal ration resulted in decreased digestibility coefficient for all nutrients, except fat in Trials 2 and 5. The digestibility of the seaweed meals tested was very low for all nutrients except fat.

The results indicate that these seaweed meals are poorly digested by the laying hen even when fed at levels as low as 10 per cent of the ration. These experiments do not support the view that seaweeds or seaweed products exert a beneficial influence upon digestion. Previous work at this Farm (4) showed that 10 per cent of seaweed meal was about the maximum which could be tolerated by hens and chickens. These results also showed that when seaweed meal was fed the birds consumed more feed. The addition of seaweed meal in excess of 10 per cent of the ration results in the consumption of excessive amounts of water and very soft droppings which may have an adverse effect on the digestibility of the basal ration with which the seaweed is fed. Work at Reading University (1) has shown that when 20 per cent of seaweed meal was fed the mineral metabolism of the birds was affected. It is possible that such a disturbance of mineral metabolism may adversely affect the digestion of other nutrients.

TABLE 4.—AVERAGE DIGESTIBILITY COEFFICIENTS [illegible]

Year	Trial number	Ration	[illegible] rations plus seaweed meals: Organic matter	Crude protein	Ether extract	Nitrogen-free extract	Crude fibre	[illegible]: Organic matter	Crude protein	Ether extract	Nitrogen-free extract	Crude fibre	[illegible]: Organic [illegible]	Crude p[illegible]	[illegible]	[illegible]	[illegible]
1952	1	Basal ration	75	82	71	75	15	—	—	—	—	—	—	—	—	—	—
	2	70% Basal + 30% Seaweed Meal	62	72	74	60	6	−17	−12	−1	−8	−60	[illegible]	[illegible]	[illegible]	42	[illegible]
1953	3	Basal ration	72	84	82	76	2	—	—	—	—	—	—	—	—	—	—
	4	70% Basal + 30% Ascophyllum	55	62	79	61	Neg.	−24	−26	−4	−20	—	19	[illegible]	76	29	Neg.
	5	70% Basal + 30% Fucus	61	69	85	65	2	−15	−18	+4	−14	—	33	23	90	31	Neg.
	6	50% Basal + 50% Fucus	43	52	73	47	Neg.	−40	−39	−11	−38	—	16	16	64	15	Neg.
1954	7	Basal ration	80	91	83	82	Neg.	—	—	—	—	—	—	—	—	—	—
	8	70% Basal + 30% Ascophyllum	58	64	79	64	Neg.	−27	−30	−5	−22	—	2	Neg.	55	24	Neg.
	9	90% Basal + 10% Fucus	72	79	82	77	Neg.	−10	−13	−1	−6	—	5	Neg.	64	26	Neg.
	10	70% Basal + 30% Fucus	57	57	81	65	Neg.	−29	−37	−2	−21	—	Neg.	Neg.	72	23	Neg.

Values represent the mean of individual determinations from six birds.

[illegible] digestibility coefficients reported in Table 4 suggest that [illegible] poorly [illegible] by the fowl. However, as mentioned [illegible] necessary to mix the seaweed meal with a basal ration, [illegible] had been previously determined. The digestibility [illegible] meal was then calculated by difference. It follows [illegible] any depression in the digestibility of the basal ration caused by mixing it with the [illegible] would cause the digestibility of the seaweed meal to [illegible] is. However, from the practical standpoint [illegible] poultry rations, it makes no difference whether its [illegible] is inherent or due to a depressing effect on the [illegible] other components of the diet. Hence, for practical purposes, the digestibility figures obtained for seaweeds in these trials may be accepted.

The low digestibility coefficients observed may be due in fact to the nature of the species under study. These two species *F. vesiculosus*, and *A. nodosum*, have been found to be inferior to other species such as *Laminaria digitata* and *L. saccharina* (9) as a food for live stock. In feeding experiments with pigs, Ringen (11) found a negative digestibility of the proteins in *A. nodosum*. Furthermore, it has been shown (10) that *A. nodosum* and *F. vesiculosus* contains a substance which reduces the [illegible] of ordinary albumins. This would account for the low, and in some cases, negative digestibility of protein. The negative digestibility of crude fibre is not surprising in view of the inability of the fowl to handle this nutrient (3).

The poor digestibility coefficients obtained in this study indicate that these two species of seaweed must be regarded as a poor source of feed for poultry. The results of these digestibility studies, therefore, confirm results previously obtained in practical feeding trials (4).

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Yakugaku Zasshi 87(8):935-9.1967

Ozawa, H., Y. Gomi, and I. Otsuki: PHARMACOLOGICAL STUDIES ON LAMININE MONOCITRATE*1 Yakugaku Zasshi, Vol. 87 (8), pp. 935-939, 1967.
Pharmaceutical Institute, Tohoku University School of Medicine, Sendai, Japan.

Laminine (5-amino-5-carboxypentyl) trimethyl ammonium was isolated from Laminaria angustata Kjellman for the first time by Takemoto et al./ 1 /, and its chemical structure has been determined / 2 /. This compound has also been found widely in weaweeds other than laminarias / 3 /. For many decades, laminaria has been used as a folk remedy for the prevention or treatment of hypertension and studies, including Kameta's clinical experiment / 4 /, demonstrated its hypotensive action. In an attempt to determine the component which directly contributes to the depression of blood pressure, Takemoto et al. successfully extracted laminine.

To the present, a few papers have been presented at medical meetings on the pharmacological action of laminine including those by Ando et al. / 5 /. This paper provides the results of an experiment on the action of laminine monocitrate on the circulatory system and excised smooth muscle preparations.

EXPERIMENTAL SECTION

EXPERIMENTAL PROCEDURE

ACTION ON BLOOD PRESSURE. Rabbit carotid artery pressure was recorded either on a smoke paper by means of a mercury manometer by the normal procedure or on a pen oscillograph by means of an electric tonometer. The respiration was recorded by connecting a tracheotomy tube to a tambour, the heart beat was computed from the electrocardiogram. The drug was administered through the aural vein, but when it was injected into the vertebral artery or the common carotid artery, a cannula was inserted into the subclavian artery and either the vertebral artery or the common carotid artery was blocked. The same procedure was applied to mice except that the drug was always injected into the femoral vein.

RECORDING OF CARDIAC MOTION.

i. Yagi's procedure: The normal procedure was followed, using toad hearts and Ringer's solution for cold-blooded animals. The drug was administered through a cannula. The apex beat was recorded on a smoke paper by means of a lever.

ii. Langendorff's Method: Guinea pig hearts were subjected to perfusion following the method employed by Burn / 6 /, Brown, and Lands / 7 /. Oxygen was introduced to Krebs-Hensleit bicarbonate solution (34 - 35°C) before use. The perfusion pressure was 20 mmHg. The heart beat was recorded on a smoke paper with a lever. The drug, 0.1 ml, was injected into the rubber tube in the upper part of a cannula.

iii. RECORDING OF IN VIVO CARDIAC MOTION. Rabbit hearts, immobilized

*1 Presented at the annual meetings of Japanese Pharmacological Society, Tohoku Regional Branch (1965, 1966).

with d-tubocurarine chloride, were exposed without opening the thoracic cavity under artificial respiration /̲ 8 /̲. Electrodes were attached to ventricular walls, and the cardiac motion was recorded on a pen oscillograph with a 2-lead impedance plethysmograph (Nihonkoden MPZ-1). During this procedure, the carotid artery pressure was also recorded with an electric tonometer. The drug was injected to theaural vein. The heart beat was computed from one of these recordings.

EXPERIMENT BY MAGNUS' METHOD. Themuscular contraction was recorded on a smoke paper with a lever by the normal procedure. The experimental conditions for each preparation are shown in Table 1.

TABLE 1. Experimental Condition in Magnus' Method

Animal	Organ	Exptl. temp. (°C)	Spasmogen	
Mouse	Small intestine	26	ACh, 5-HT, Ba^{2+}	Tyrode soln.
Guinea pig	Small intestine	26	ACh, hist	〃
〃	Aorta	37	NA	〃
〃	Trachea	37	—	〃
〃	Vas deferens	31	NA, Iso	〃
Frog	Rectus abdominis muscle	room temp.	ACh	Ringer soln.

TEST COMPOUNDS: The compounds used for the experiment are as follows: laminine monocitrate (Lam), mol. wt. 380 and readily soluble in water; drenaline (NA); isoproterenol HCl (Iso); acetylcholine chloride (ACh); atropine sulfate (Atr); papaverine HCl (Pap); histamine 2HCl (hist); serotonin creatinine sulfate (5-HT).

EXPERIMENTAL RESULTS

ACTION ON BLOOD PRESSURE. Lam, 10 - 30 mg/kg i.v., depressed rabbit carotid artery pressure by 20 - 40 mmHg, but the depressive action was transitory. It also stimulated the respiration temporarily at 20 mg/kg i.v., but the change was not significant (Figure 1). Since the hypotensive action of Lam showed no response to a pretreatment with Atr at 2 mg/kg, it is assumed to be non-cholinergic. Lam exhibited no effect on the hypertensive reaction due to bilateral carotid occlusion or intravenous administration of Na at 5 ug/kg. This was also noted in mice.

The administration of Lam through the vertebral artery (5 mg/kg) or the common carotid artery (10 mg/kg) was also followed by transitory depression, but the time up to the manifestation of such effect was short as compared to that following the injection through the aural vein, suggesting that the depressive action takes effect at a site higher than the site of injection as well.

ACTION ON THE HEART.

i. Yagi's procedure (toad): Lam at over 10^{-4}M caused a decrease in amplitude in excised toad heart, followed by an increase in some cases. At over 10^{-3} M, the cardiac motion stopped in most cases. However, no change in heart beat was noted, except when the treatment was continued for a prolonged period which eventually produced brachycardia in some cases. The decrease in amplitude and brachycardia were not antagonized by Atr at 1×10^{-4} M, but mutual antagonism with Na at $1 - 5 \times 10^{-5}$ was noted.

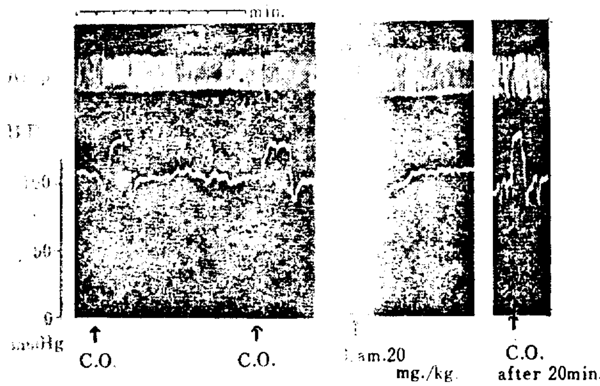

Fig. 1. Influence of Laminine Monocitrate on Blood Pressure and Pressor Response by Bilateral Carotid Occlusion in Urethane Anesthetized Rabbit

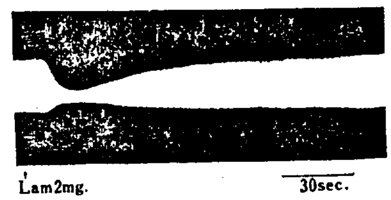

Fig. 2. Effect of Laminine Monocitrate on Langendorff's Heart Preparation of Guinea Pig

ii. Langendorff's Procedure (guinea pig): Lam at over 1 mg reduced the cardiac movement to a notable degree, although the change was transitory and the heart beat remained without change (Figure 2). Lam at 5 mg temporarily suspended cardiac pulsation, but repeated perfusion brought back normal condition. The transitory cardiac suppression by Lam was not antagonized by Atr at 0.1 mg (a dose producing antagonism against 1 ug of ACh), but mutual antagonism with Ca^{++} at 600 ug and Na at 0.5 mg was noted. The perfusion of the preparation with Lam at 50 ug/ml inhibited cardiac pulsation and weakened its reactivity toward Na (Figure 3), but withdrawal of the perfusion normalized the condition.

Since Lam is used in the form of a monocitrate, the effect of citrate was also studied by administering Na citrate of the equal mole. A weak inhibitory action was observed, but the degree of inhibition was considerably [illegible]r than that of Lam.

iii. In-situ Heart Movement (rabbit): Lam at 30 mg/kg i.v. inhibited cardiac palpitation, but the change in heart beat was minimal (Figure 4). Bilateral vagotomy did not supress but somewhat intensified the inhibitory action. The time course was short as compared to that in its hypotensive action in both cases. Thus, the vagus nerve cannot be the center of its depressive action.

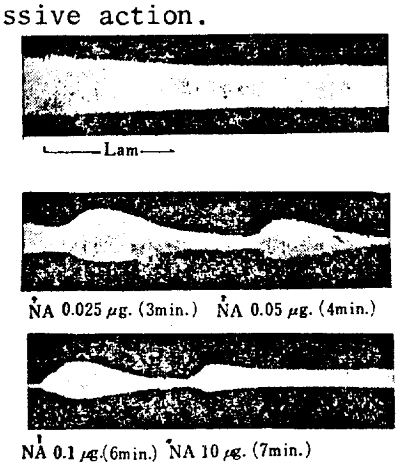

Fig. 3. Effect of Perfused Laminine Monocitrate (50 μg./ml.) on the Activity and Responsibility to Noradrenaline of Langendorff's Heart Preparation of Guinea Pig

Nos. in parenthesis show the time after the begining of perfusion

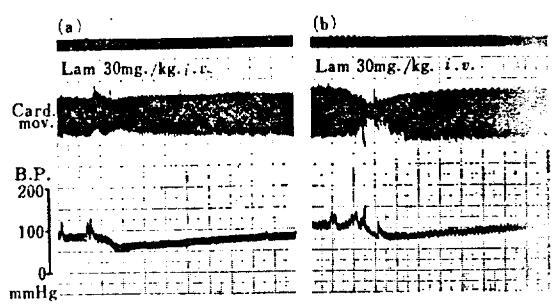

Fig. 4. Effect of Laminine Monocitrate on Cardiac Movement and Blood Pressure of Curarized Rabbit

(a) before and (b) after bilateral vagotomy

ACTION ON EXCISED SMOOTH MUSCLES. The actions of Lam at 1 x 10^{-3} M on major muscle preparations are shown in Table II.

TABLE II. Effects of Laminine Monocitrate ($1 \times 10^{-3} M$) on Muscle Preparations

Animal	Organ	Spasmogen (M)	Response (%)
Mouse	Small intestine	ACh 1.0×10^{-4}	-70.7 ± 3.9
Guinea pig	Small intestine	ACh 1.0×10^{-6}	-5.9 ± 5.4
〃	〃	hist 1.0×10^{-7}	-97.8 ± 1.3
〃	Vas deferens	NA 5.3×10^{-5}	$+192.7 \pm 40.7$
Frog	Rectus abdominis muscle	ACh 1.0×10^{-5}	-21.4 ± 4.6
		〃 1.0×10^{-4}	-3.4 ± 3.2

i. Mice small intestine: Lam at over 10^{-4} M suppressed the intestinal contraction induced by ACh, Ba^{++} (1.23 x 10^{-3} M) and 5-HT (1 x 10^{-5} M). The rate of inhibition, calculated using ACh at 1 x 10^{-4} M by the 4-point method at ED 50 of 7.6 x 10^{-4} M was 0.93% of Pap. Lam at 3 x 10^{-5} M did not suppress but potentiated the intestinal contraction induced by ACh at 1 x 10^{-5} M. After the ACh-induced contraction was suppressed with Lam at over 10^{-4} M, the small intestine was washed and treated with ACh at the same concentration. As a result, the height of contraction was elevated and repeated washing normalized the reactivity. The mechanism involved in this phenomenon is undetermined.

ii. Guinea pig small intestine: Lam exhibited its anti-histamine action (his, 1 x 10^{-7} M) at 1 x 10^{-5} M. It suppressed muscular contraction nearly completely at 1 x 10^{-3} M. The ED 50 was 2.2 x 10^{-4} M. However, its anti-acetylcholine action in guinea pig small intestine was weak, the contraction inhibition ratio at 1 x 10^{-3} M being only 6% (Figure 5).

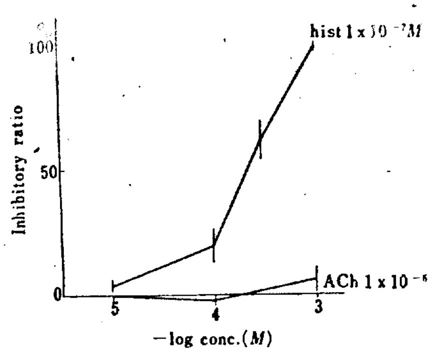

Fig. 5. Spasmolytic Action of Laminine Monocitrate in Small Intestine of Guinea Pig
vertical line: S.E.

iii. Smooth muscle of guinea pig aorta: Lam reduced the muscular tension at over 4 x 10^{-4} M, and antagonized the contraction induced by Na at 4.9 x 10^{-9} M.

iv. Smooth muscle of guinea pig trachea: Similarly, Lam at 6 x 10^{-4} M reduced the muscular tension.

v. Vas deferens of guinea pig: Lam at 2.5 x 10^{-4} M and 1 x 10^{-3} M potentiated the contraction induced by Na at 5.3 x 10^{-5} by 24 and 193%, respectively. The contraction induced by Iso at 8 x 10^{-4} M was also potentiated. However, no effect of Lam was noted at 2.5 x 10^{-7} to 2.5 x 10^{-5} M. Lam exhibited no antagonism against Na or Iso.

ACTION ON RECTUS ABDOMINIS MUSCLE OF TOAD: As shown in Table II, the inhibitory action of Lam on these preparations was weak. The contraction induced by ACh at 1 x 10^{-5} and 1 x 10^{-4} was inhibited 21.4 and 3.4%, respectively, at 1 x 10^{-3} M.

ACUTE TOXICITY AND SLEEP PROLONGATION ACTION. For mice, the LD 50 by the intravenous route is 394 mg/kg (up and down method), and that by the hypodermic route is 2.98 - 3.57 g/kg. Intravenous injection of this compound at a lethal dose causes death within several minutes following spasm and opisthotonus. However, intraperitoneal administration or hypodermic injection of Lam at smaller dose (e.g., 500 mg/kg i.p.) is responded by no characteristic change other than weak tremor of the hind legs and hypomotility. Intraperitoneal administration at 200 mg/kg exhibited no effect. The duration of sleep induced in mice by cylobarbital Na at 80 mg/kg i.p. 10 minutes after intraperitoneal injection of Lam at 500 mg/kg was 82.5 min, without a significant difference from 60.9 min of the control. Thus, no sleep prolongation effect was observed.

DISCUSSION

Since lamine, a crystalline substance, was discovered during an experiment on the hypotensive component of laminaria, its depressive action particularly drew interest. As described in the experimental section, its depressive action was observed at a dose over 10 mg/kg, but its duration was short. Ando et al. /̄5̲/ observed depression by 20 - 30 mmHg upon intravenous injection of laminine hydrochloride 30 at 100 mg/kg. They stated that atropine did not affect its hypotensive action and Lam caused no change in the hypertensive action of noradrenaline or bilateral carotid occlusion. Although the site of action is not clear, its direct dilatation action on the peripheral blood vessels seems to be the most probable derivation of the effect, judging from the changes in the heart and smooth muscles induced by this compound.

The action of laminine on the heart is manifested as the suppression of <u>in situ</u> and <u>in vitro</u> cardiac movement, but the heart beat showed no change and the amplitude became reduced. A single administration of Lam caused a transitory change, and, as shown in Figure 4, its duration is shorter than the time course of its hypotensive effect. Furthermore, the perfusion of the muscle preparations not only suppressed the contraction but reduced the sensitivity toward noradrenaline. Its suppressive action on the heart was not antagonized by atropine. Ando et al. /̄5̲/ a slight increase in amplitude in Langendorff preparations, but the present experiment revealed no increase.

Laminine reduced the tension of the smooth muscles of mice small intestine, and guinea pig small intestine, aorta, and trachea, and antagonized the contraction induced by acetylcholine and histamine. The concentration at which Lam manifests such action is relatively high, but the antihistamine action in guinea pig small intestine was relatively strong. Lamine also inhibited the contraction of the rectus abdominis muscle of toad, but its effect was weaker than that on the smooth muscle.

As described above, laminine possesses inhibitory action on the heart and other preparations, but the manifestation of such effects require relatively high concentrations. In view of the fact that it antagonizes acetylcholine, serotonin, and Ba^{++} to an equal degree as noted in mice small intestine, its action is assumed to be musculotropic. Moreover, its action is transitory as noted in Langendorff's specimens, and the normal condition is recovered immediately when the drug is removed. Based on these observations, it is assumed that its musculotropic dilatation action on the peripheral blood vessels contributes considerably to the transitory depression of blood pressure. It must be noted, however, that this assumption was drawn from an acute toxicity experiment by single administration of the compound. Its effect on blood pressure in prolonged use and its possible cholesterol-reducing effect, in view of its efficacy toward hypertension as is suggested by its traditional use as a folk remedy for this purpose, must be investigated.

The action of laminine on guinea pig vas deferens was quite different from that on other organs in that it stimulated the contraction produced by noradrenaline and isoproterenol without sign of antagonism. Its stimulatory action on muscular contraction was occasionally shown by mice small intestine after laminine was washed off, although the degree of stimulation was not as notable as that in vas deferens. The mechanism of such stimulatory action could not be fully clarified in this experiment, but it seems to be of considerable interest.

CONCLUSION

The present study on the pharmacological action of a seaweek component, laminine monocitrate, yielded the following results.

1. The acute toxicity of laminine is extremely weak, the LD 50 by intravenous injection in mice being 394 mg/kg, and the LD by hypodermic injection being 2.98 - 3.57 g/kg.

2. Laminine inhibits cardiac motion in situ and in vitro and exhibits a transitory hypotensive action, but causes no change in heart beat.

3. Laminine reduces the tension of the smooth muscles from the small intestine, blood vessels and trachea, and inhibits the contraction induced by various drugs. Its effect on toad rectus abdominis muscle is weak as compared to that on the smooth muscle preparations, and it stimulates the contraction of guinea pig vas deferens.

3. The mode of its hypotensive action and inhibitory action on smooth muscle contraction is yet to be determined, but its action is assumed to be musculotropic rather than neurotropic.

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12.

SEAWEED (*LAMINARIA*) AS STOCK FOOD.

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SELECTED species of seaweed have long been used, even if only to a limited extent, as human food. Carrigeen in the dried form has developed into an article of commerce, while coast dwellers in certain districts consume other species prepared in the fresh condition, and served as a delicacy.

As a stock food seaweed also plays a part. Livestock grazing near the seashore frequently show a partiality for the intertidal flora. Hereus (1) for instance reports that, in parts of New Zealand, sheep "show a remarkable craving for seaweed." Numerous references from north European countries go to show that seaweed, when other foods are scarce, is consumed rather freely by stock, while in times of dearth it may occasionally form the sole food for, at least, a limited period. In parts of New Zealand it forms an appreciable portion of the food of livestock (2). Seaweed is freely fed to stock in Lapland and in the Faroe and Orkney islands. The drying and grinding of seaweed into edible meal is a commercial process in more than one country. A factory operating on the west coast of Ireland, in Co. Clare, prepares dried seaweed into a meal suitable for feeding to farm animals.

PROCEDURE.

In an endeavour to assess the nutritive value of laminaria, one of the genera of seaweed which grows freely around our coasts, and which is cast up on the beach as a tidal deposit

a digestion experiment has been conducted on two pigs of approximately 250 lb. each. A sample of *Laminaria digitata* collected on the west coast in the month of September was air dried, in which condition it contained 22 per cent. of moisture, cut into small portions in a straw chopper, dried in a current of air at 70° C., and ground into a fine meal in a laboratory hammer mill. The proximate composition of the seaweed meal so prepared, expressed as dry matter, was as follows:—

ash	16·38 %	including 2·55 % chlorine and 2·0 % calcium.
crude protein	7·82 %	
ether extract	0·40 %	
crude fibre	6·93 %	
nitrogen-free extract (by difference)	68·47 %	

The digestion experiment covered three periods, in the first of which a basic ration which was complete and adequate for the maintenance of the animals was fed. In period 2 a quantity of untreated laminaria meal was added to this basic ration, and in period 3 a like quantity of hydrolysed laminaria was added to the same basic ration, hydrolysis having been effected by boiling the weed with 5 per cent. sulphuric acid for an hour, neutralising subsequently with soda.

The basic ration used was a mixture of the following:—barley meal, 40 parts; wheat pollard, 40 parts; wheat bran, 10 parts; meat meal, 10 parts; common salt, 1 part. An analysis of this feed was made, and the quantity of each constituent ingested and excreted daily in period 1 determined. The excess of each constituent excreted in periods 2 and 3 over that of period 1 was regarded as equivalent to the undigested portion of that constituent consumed in the untreated seaweed meal and hydrolysed seaweed meal, respectively. Because of the unsuitability of seaweed to form the sole diet of the pig it is unfortunately necessary to determine its digestibility by difference as described.

Each pig was fed twice daily. The duration of each test period was 16 days, during the last 10 days of which the faeces were collected and weighed for analysis. Crude protein was determined on the fresh material: all other determinations were made on the dried foods and faeces. Between the periods the pigs were set at liberty in an open pen for some days. While salt was added to the basic ration of period 1 it was withheld from the combined basic ration—seaweed ration of periods 2 and 3 because of the relatively high salt content of the seaweed.

RESULTS.

The results are given in tabular form below:—

TABLE 1.—*Daily ration of each pig (grams).*

	Period 1.	Period 2.	Period 3.
Barley meal	720	720	720
Pollard	720	720	720
Bran	180	180	180
Meat Meal	180	180	180
Salt	18	—	—
Seaweed	—	600	—
Seaweed hydrolysed ...	—	—	600

TABLE 2.—*Analyses of Foods (%).*

	Moisture.	Ash.	Crude protein.	Ether extract.	Crude fibre.	Nitrogen-free extract.
Mixture of meals fed in periods 1, 2, and 3, as a basic ration	14·30	7·98	16·05	1·97	5·62	54·08
Seaweed fed in period 2 ...	10·50	11·66	7·00	0·36	6·20	61·28
Hydrolysed seaweed fed in period 3	14·19	15·85	6·56	0·31	6·00	57·09

TABLE 3.—*Constituents ingested by each pig daily (grams).*

	Dry Matter.	Ash.	Crude protein.	Ether extract.	Crude fibre.	Nitrogen-free extract.
As basic meal mixture in each of period 1, 2, and 3	1542·60	143·61	288·90	35·46	101·16	973·44
As seaweed in period 2 ...	537·00	87·96	42·00	2·16	37·20	367·68
As hydrolysed seaweed in period 3	514·86	95·10	39·36	1·86	36·00	342·54

TABLE 4.—*Constituents excreted daily (grams).*

		Dry Matter.	Ash.	Crude protein.	Ether extract.	Crude fibre.	Nitrogen-free extract.
Pig A	Period 1 ...	475·00	105·87	63·60	8·62	87·50	203·41
	,, 2 ...	637·60	145·66	93·00	5·65	105·61	290·28
	,, 3 ...	661·50	153·11	92·63	12·63	109·65	293·48
Pig B	Period 1 ...	465·70	109·46	60·55	8·41	86·89	200·39
	,, 2 ...	652·70	150·14	92·23	5·78	106·24	298·05
	,, 3 ...	671·00	148·26	97·23	13·14	106·55	305·82

TABLE 5.—*Constituents retained from seaweed and hydrolysed seaweed (grams).*

		Dry Matter.	Crude Protein.	Ether extract.	Crude fibre.	Nitrogen-free extract.
From seaweed—period 2	Pig A	374·40	12·60	5·13	19·09	280·81
	Pig B	350·26	10·32	4·79	17·85	270·02
From hydrolysed seaweed—period 3	Pig A	328·36	10·33	– 2·15	13·85	252·47
	Pig B	309·56	2·68	– 2·87	16·34	237·11

TABLE 6.—*Digestibility co-efficients of seaweed and hydrolysed seaweed.*

		Dry Matter	Crude protein.	Ether extract.	Crude fibre.	Nitrogen-free extract.
Seaweed—period 2 ...	Pig A	69·7	30·0	210·3	51·3	76·4
	Pig B	65·2	24·6	221·6	48·0	73·4
Hydrolysed seaweed—period 3	Pig A	63·8	26·2	– 115·6	38·5	73·7
	Pig B	60·1	6·8	– 154·7	45·4	69·2

The extraordinary digestibility figures obtained for ether extract are not unusual in work of this kind where the quantity of ether extract dealt with is, as in the case of seaweed, exceedingly small. Approximately one-quarter of the crude protein and about half of the fibre of the unhydrolysed seaweed are apparently digestible, while the digestibility of the nitrogen-free extract is in the neighbourhood of 75 per cent. Curiously, the digestibility of the hydrolysed seaweed shows up no higher than that of the unhydrolysed material: in fact it is consistently lower, not alone in respect of dry matter, but of all the constituents which enter into its composition. Seaweed is definitely laxative in effect, so that the amount which is capable of being fed is limited. The maximum consumption of laminaria by a 2 cwt. pig is approximately 2 pounds daily.

Discussion.

In considering the apparent digestibility and, by deduction, the nutritive value of seaweed its physical character must be borne in mind. It has the power of absorbing a very considerable proportion of water, forming a thick stiff jelly mass, which, as the water absorption is increased, changes to a glutinous or slimy consistency. Materials of this nature when fed with discretion exercise a very favourable influence on the action of the large bowel, in which the optimum state of affairs is produced by a type of content which, while dilating the tube considerably, produces no semblance of irritation in passing along the tube. Bowel movement is facilitated, and the evacuation of the gut is made regular and complete. All such foods when included in a complete diet favour a gloss of coat and bloom of skin which are associated with good health. Seaweed is of this category of foods which presumably enhance the value of the other foods in conjunction with which they are fed. It is therefore conceivable that the comparatively high digestibility figures obtained for seaweed in this experiment are more apparent than real, being possibly explained in part by the enhancement, by the seaweed, of the nutritive value of the basic ration in

conjunction with which it was fed. However, to the animal, the result is the same whether the extra nutriment absorbed when seaweed is added to a basic ration comes entirely from the seaweed, or partly from it and partly as a result of improved utilisation of the basic ration. That the latter is the more correct explanation is suggested by the fact that the hydrolysed weed did not prove superior to the non-hydrolysed. The weed loses its gelling properties, and presumably its favourable physical effect on the alimentary tract as a result of hydrolysis, and this loss may counterbalance, or even more than counterbalance, the increased availability of the ingredients of the seaweed brought about by hydrolysis.

The laminariae are predominantly carbohydrate in composition. The compounds of the carbohydrate class which have so far been isolated from the plants are alginic acid, mannite, fucoidin, cellulose and laminarin. The percentages of all these constituents undergo a considerable seasonal variation, and, since they are not all equally digestible, it is important in feeding experiments with seaweeds to state the period at which the weed has been harvested—a point which does not hitherto appear to have received the attention it deserves. Lunde (3) has studied this seasonal variation, and in the following brief account of the carbohydrates of the laminariae the figures for seasonal variation are quoted from his paper.

Alginic acid is a polymer of mannuronic acid (4). In constitution it bears some resemblance to the pectins of the higher plants, which contain galacturonic acid. The pectins are, however, more complex. The mode of occurrence or state of combination of alginic acid in the plant is somewhat obscure (5). Waksman and Allen (6) have isolated from soil and from sea water bacteria which decompose alginic acid; but the enzymes of higher organisms appear to be without action on it. The alginic acid content of the laminariae reaches a maximum of about 30 per cent. of the dry matter in the spring, and falls to a minimum of 15 per cent. in November.

Fucoidin is a mucilage, and, according to Lunde (3), is an ethereal sulphate of a polymeric carbohydrate, the units of which consist, in part at least, of the methyl pentose fucose (d-galactomethylose). Mucilages are not digestible by the digestive glands of higher animals. In the laminariae, fucoidin is at a minimum of about 4 per cent. of the dry matter in the spring, and a maximum of about 8 per cent. in August and September.

Mannite, $C_6H_{14}O_6$, is a hexahydric alcohol with the same configuration as mannose. It is probably freely digestible. The content in the laminariae varies from a minimum of 3–4 per cent. in the winter to a maximum of 15–17 per cent. in the summer.

That true cellulose exists in the laminariae was shown some years ago (7), and unpublished determinations made from time to time in the laboratory of one of the authors (T.D.) go to show that its quantity varies between 5 and 10 per cent. of the dry weight of the plant.

Laminarin is apparently the chief reserve carbohydrate of the laminariae. Its formula is $(C_6H_{10}O_5)_n$, and it resembles starch in being composed entirely of glucose units (8). It, however, differs from starch in constitution in two important respects. In the first place, whereas in starch the glucose units are united through the first and *fourth* carbon atoms, in laminarin the union is between the first and *third* (9). In the second place, whereas in starch the glucose units have the α configuration, in laminarin the configuration is β (10). Like starch laminarin is soluble in water, and is easily hydrolysed by dilute acids; but Colin and Ricard (11) have shown that it is not affected by the common amylases or by emulsin. The same authors have found that it is hydrolysed by the gastric juice of the snail. These results have been confirmed by Barry, who found that the gastric juice of the limpet (Patella) was also capable of bringing about the hydrolysis (10). In the spring laminarin is completely absent from the laminariae; the supply is built up gradually during the summer months, and in the autumn the quantity present may be as much as 20 per cent. of the dry weight of the plant.

The resemblance between starch, the chief carbohydrate food of land plants, and laminarin leads one to believe, at first sight at least, that if seaweeds have any nutritive value it will be due to their laminarin content. On the other hand, the constitutional differences between starch and laminarin, as well as the resistance of the latter to the common amylases, make it necessary to discover by experiment whether laminarin is actually digestible. Accordingly an autumn weed rich in laminarin was chosen for these experiments, and the quantity of the carbohydrate in the food and in the faeces was determined (see Appendix).

No laminarin was found in the faeces of the animals fed on the seaweed containing laminarin, and therefore it would appear that it is completely digested. The experiments, however, seem to show that it was not the only carbohydrate digested. The nitrogen-free extract content of the laminaria used was 61·28 per cent., the digestibility coefficient of which was 73·4–76·4 per cent. Thus, every hundred pounds of the laminaria ingested contained about 46 pounds of digestible nitrogen-free extract, of which only 15 pounds was laminarin. Hence, a considerable quantity of carbohydrate other than laminarin must have been digested.

It is well known that the digestion of cellulose by farm stock depends on the activity of the bacterial flora of the alimentary tube. Presumably, the bacteria are also chiefly responsible for the digestion of the carbohydrates of the laminariae. The pectins of land plants, which resemble somewhat the alginic acid of seaweed, are for instance, according to Werch and Ivy (12), digested by the dog and human to the extent of almost 90 per cent. of the amount ingested. They find that the breakdown of the pectin occurs, not in the small intestine, but chiefly in the colon, where bacterial action is largely responsible for the process. That the digestion of seaweed is largely attributable to bacteria is also indicated by the results of Ringen (13), who found that the feeding value is greater for sheep than for pigs.

On the assumption that the figures given in Table 6 represent the true digestibility of the laminaria fed, the total digestible nutrients[1] of the sample, which contained [illegible] per cent. dry matter, work out at approximately 50. By comparison the total digestible nutrients of potatoes, hay, and oats, are 19, 40, and 60, respectively. Thus, laminaria dried to 10 per cent. of moisture, ground, and fed in conjunction with other foods, would for pigs appear to have a value approximately two and a half times that of potatoes, and somewhere intermediate between hay and oats. It is unwise, however, to assign a specific nutritive value to any food as a result of a single digestion experiment. Ringen (13) places the value of ground dried seaweed as approximately equivalent to good hay, whilst Lunde (14) concludes that seaweed harvested in autumn is intermediate in value between hay and oats. In comparison with potatoes and cereals laminaria is a rich source of calcium and chlorine, whilst its physical effect on the alimentary tube of the animal is superior.

Summary.

1. Using pigs as experimental animals the digestibility coefficient of seaweed (*Laminaria digitata*) ground to meal has worked out at approximately 67 and 75 for the organic matter and nitrogen-free extract, respectively.

2. On the assumption that the digestibility figures are true rather than apparent, the total digestible nutrients of the meal, containing 10 per cent. of moisture, are calculated at 50, in comparison, for instance, with 20 for potatoes.

3. The very favourable mechanical effect of seaweed on the alimentary tube of the animal, which is associated with its gelling properties, by possibly enhancing the remainder of the ration with which the seaweed was fed in this experiment, may be partly responsible for its apparently very high nutritive value, the fixing of which at a definite level from the result of a single digestion experiment on two pigs is unwarranted.

4. All the laminarin and at least portion of the other carbohydrate constituents of laminariae are digestible.

5. The digestibility of laminaria is not improved by hydrolytic treatment.

6. Laminaria is predominantly carbohydrate in composition: it is, however, rich in minerals, being a good source of calcium and chlorine.

[1] The figure for total digestible nutrients was obtained by adding together the number of pounds of digestible protein, digestible fibre, and digestible nitrogen-free extract obtainable from 100 pounds of the laminaria fed: on account of the very low content of ether extract, and the abnormal figures for its digestibility, the ether extract content of laminaria was ignored in calculating the total digestible nutrient in this [illegible]

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APPENDIX.

Determination of Laminarin.

(1) *In the Seaweed Meal.*—12·2256 g. of the meal were boiled with 200 c.c. of water under a reflux condenser for $3\frac{1}{2}$ hours. The aqueous extract was separated from the residual solid by centrifuging. 50 c.c. of the extract were treated in a 100 c.c. measuring flask with 10 c.c. of a solution of basic lead acetate, and the mixture was made up with water to 100 c.c. The contents of the measuring flask were transferred to an ordinary flask, heated under a reflux condenser until the precipitate had coagulated, and then filtered. The rotatory power of the clear filtrate in a 20 cm. tube was $-0{\cdot}175$ (D line). 50 c.c. of this filtrate were saturated with sulphuretted hydrogen gas, and, after filtering off the lead sulphide, were treated with 25 c.c. of 3 % hydrochloric acid. The acid solution was heated under a reflux condenser to hydrolyse the laminarin. After 3 hours' heating the rotatory power of the solution in a 20 cm. tube was $+0{\cdot}345$, and did not change on further heating. The hydrolysed extract was neutralised with solid sodium carbonate, and the rotation was again observed. The value found was $+0{\cdot}346$. The liquid was now fermented with yeast, and at the conclusion of the fermentation its rotatory power was $-0{\cdot}018$. The corrected rotatory power of the glucose in the solution before fermentation was therefore $0{\cdot}346 + 0{\cdot}018 = +0{\cdot}36$. From these data the total glucose obtained from the meal taken was calculated to be 2·04 g., and from this the percentage of laminarin in the meal was calculated to be 15·03.

In another experiment 11·991 g. of the meal were boiled with 200 c.c. of concentrated hydrochloric acid under a reflux condenser for $3\frac{1}{2}$ hours. 100 c.c. of the resulting extract were neutralised with sodium carbonate, and made up to 230 c.c. The rotatory power of this solution (20 cm. tube, D line) was $+0{\cdot}367$. The solution was now fermented with yeast, and after fermentation the rotatory power was $-0{\cdot}028$. Hence the corrected rotatory power of glucose solution was $+0{\cdot}39$. From this the percentage of laminarin in the weed was calculated to be 15·36.

The mean value for the percentage of laminarin from the two experiments was 15·2.

(2) *In the Faeces.*—Weighed quantities of the faeces of pigs A and B for the three periods were extracted with boiling water, as in the first experiment with the seaweed meal. After defecation with lead acetate at pH 6·8, the solution in all cases was optically inactive before and after hydrolysis, and did not reduce Fehling's solution.

In the above determinations, the weights of faeces taken for period 2 (when the animals were being fed on seaweed meal) were: for pig A 8·9176 g. and for pig B 9·320 g., while the volume of water used to extract was in each case 250 c.c. 100 c.c. of the centrifuged extract were defecated with lead acetate, and the precipitate was filtered off. The precipitate was well washed, and precipitate and washings were reduced in bulk by evaporation, and made up to 100 c.c. This solution was treated with sulphuretted hydrogen gas, and filtered from lead sulphide. The filtrate was optically inactive. 50 c.c. of the filtrate were treated with 2 c.c. of concentrated hydrochloric acid, heated on the water bath for 4 hours, and again made up to 50 c.c. This solution, in which any laminarin present would now be hydrolysed to glucose, was optically inactive.

The polarimeter would detect a concentration of 0·02 per cent. of glucose; therefore the 250 c.c. of extract did not contain as much as 0·05 g. of glucose. Hence the weights of faeces taken did not contain as much as 0·05 g. of laminarin. The faeces therefore did not contain as much as 0·6 per cent. of laminarin.

34.

THE INFLUENCE OF KELP MEAL FEED ON THE IODINE CONTENTS OF THE HEN'S EGGS

By

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It has been observed that the iodine content of the hen's egg is increased when potassium iodide or some other iodine compound is given to the laying hen. (J. Straus, 1933; R. Sasaki, 1930.)

In the present investigation an attempt has been made to measure the iodine content of the hen's egg when kelp meal (Ecklonia Cava) has been given to the laying hen in varying quantities.

It may be observed that the lack of iodine in human food is made good by eating hens' eggs produced by kelp meal feeding.

Proc. World's Poultry Cong.
6th Cong. Berlin and Leipzig
Sect. 2: 343-346, 1936

I. Method

Four laying hens (White Leghorn) were placed in battery and divided in to two lots, viz. A and B. This experiment lasted 20 days, and during this period kelp meal was given in capsules to lots A and B regularly every morning in quantities of 5 g. (13.9 mg. 1) and 10 g. (27.8 mg. 1) respectively. The basal diet used in this experiment was as follows,

Mash (parts by weight) (Ad Libitum in hopper)		Scratch (parts by weight) (40 g per bird a day)	
Rice bran	20	Maize	40
Wheat bran	25	Wheat	30
Barley bran	10	Barley	30
Soyabean cake	10		
Fish meal	20		
Maize	15		
Mixed salts	5		

Throughout the entire period of the experiment eggs were weighed, and then, after the shell had been well washed boiled in the water so as to cause coagulation of the contents. The yolk was separated from the white, and the iodine contents in each part were measured.

Determination of iodine

Place the material in a nickel dish, add 10 cc. of 20 % KOH solution and mix well. Ignite carefully at a low red heat to destroy organic matter. Extract the residue by means of a small quantity of water and alcohol several times, and finally filter. Ignite the residue together with filter paper and extract the residue by means of alcohol. Combine the washings and filtrates, evaporate it to dryness, add 50 cc. of distilled water, slightly acidify with sulphuric acid, using methyl orange as an indicator. Boil to expel CO_2, add bromine water and heat it, after the liquid has become colorless, continue boiling for five minutes.

After cooling, add a small piece of potassium iodide crystal to the solution, and titrate with 0.005 N thiosulphate solution (1 cc. = 0.1058 mg. 1) using starch solution as an indicator.

The iodine content of each fraction obtained by extracting the yolk and white by means of ether, hot water and alcohol successively, was also measured.

II. Results

Throughout the period of the experiment, the birds were all in a good state of health.

Their weights and egg-laying conditions were as follows,

	Bird No.	Number of Eggs produced	Weight Before experiment	Weight After Experiment
Lot A	3-63	18	1880 g.	1860 g.
	3-221	16	2045 g.	1970 g.
Lot B	3-240	16	1800 g.	1850 g.
	3-242	17	1720 g.	1740 g.

The yolk was separated from the white of each egg and the iodine content was determined by the method as stated above, and the following results being obtained:

Test Period	Date	Lot A (Kelp Meal 5 Grams)						Lot B (Kelp Meal 10 Crams)					
		Bird No. 3—63 Amount of Iodine			Bird Nr. 3—221 Amount of Iodine			Bird No. 3—240 Amount of Iodine			Bird No. 3—242 Amount of Iodine		
		Weight of Egg g.	White of Egg mg.	Yolk of Egg mg.	Weight of Egg g.	White of Egg mg.	Yolk of Egg mg.	Weight of Egg g.	White of Egg mg.	Yolk of Egg mg.	Weight of Egg g.	White of Egg mg.	Yolk of Egg mg.
Basal Diet	May 17	55.5			—			—			61.1		
	18	56.1	0.002 (Average)	0.005	57.8			53.3			58.7	0.002 (Average)	0.004
	19	—			59.9	0.001 (Average)	0.004	51.8	0.003 (Average)	0.003	—		
	20	57.4			51.3			53.9			64.1		
Basal Diet + Kelp Meal	21	60.4	—	—	56.6	0.003	0.005	—	—	—	61.8	—	—
	22	57.5	0.052	0.008	54.2	0.018	0.007	54.2	0.096	0.015	—	—	—
	23	55.2	0.038	0.091	54.3	0.095	0.045	54.6	0.111	0.076	60.0	0.096	0.100
	24	54.5	0.047	0.326	—	—	—	53.1	0.123	0.240	59.8	0.154	—
	25	62.2	0.074	0.366	57.0	0.086	0.288	53.7	0.145	0.580	—	—	—
	26	59.5	0.076	0.571	53.9	0.083	0.722	53.2	0.178	0.879	62.8	0.204	0.662
	27	56.6	0.088	0.672	56.8	0.090	0.599	53.3	0.165	1.110	61.4	0.194	1.178
	28	58.3	0.068	0.748	—	—	—	52.0	0.168	1.052	60.5	0.181	1.260
	29	57.0	0.061	0.698	57.0	0.078	0.806	—	—	—	58.0	0.180	1.301
	30	56.9	—	—	56.7	0.084	0.750	53.8	0.216	1.209	57.3	—	—
	31	—	—	—	56.9	0.061	0.589	55.7	0.213	1.526	—	—	—
	June 1	59.0	0.114	0.890	56.3	0.103	0.652	51.4	0.230	1.386	63.7	0.215	1.488
	2	59.7	0.131	0.731	57.1	—	—	—	—	—	64.0	0.155	1.291
	3	57.1	0.101	0.877	—	—	—	51.4	0.233	1.222	60.1	0.160	1.330
	4	58.9	—	—	57.3	0.116	0.872	52.0	—	—	60.3	—	—
	5	56.7	—	—	57.2	0.123	0.938	51.3	0.173	1.435	60.2	0.191	1.175
	6	55.3	0.099	0.842	56.3	0.129	1.084	—	—	—	58.5	0.308	1.309
	7	55.5	0.139	0.797	57.7	—	—	54.5	0.261	1.285	—	—	—
	8	55.9	0.123	0.825	—	—	—	52.1	0.235	1.298	60.1	0.306	1.320
	9	—	—	—	55.7	0.096	1.073	51.5	0.166	1.310	59.2	0.332	1.545
Basal Diet	10	55.8	0.165	1.027	57.8	0.156	0.998	52.5	0.196	1.395	60.7	0.194	1.592
	11	57.3	0.154	1.033	60.0	0.092	1.058	—	—	—	60.0	0.160	1.459
	12	57.3	0.045	1.041	54.2	0.056	0.976	53.9	0.100	1.223	58.5	0.090	1.641
	13	58.2	0.016	1.017	—	—	—	55.1	0.074	1.185	59.2	—	1.099
	14	56.1	0.010	0.829	56.3	0.014	0.902	55.0	0.026	1.095	57.5	0.065	0.993
	15	53.9	—	—	57.5	0.004	0.483	54.8	0.006	0.764	60.2	0.006	0.730
	16	—	—	—	—	—	—	—	—	—	—	—	—
	17	—	—	—	—	—	—	—	—	—	—	—	—
	18	57.4	0.008	0.032	57.7	0.003	0.030	52.7	0.003	0.056	58.7	0.003	0.035
	19	—	—	—	—	—	—	—	—	—	—	—	—
	20	—	—	—	—	—	—	—	—	—	—	—	—
	21	58.6	0.004	0.014	59.1	0.003	0.007	57.1	0.003	0.012	58.2	0.003	0.014

Summary

1. In the case of feeding on the basal diet, the iodine contents per egg were 0.0015 mg. in the white and 0.0040 mg. in the yolk, whereas where kelp meal was given to the hen with the basal diet, iodine contents increased rapidly in the white and slowly in the yolk.

The maximum iodine contents observed during the experiment were as follows.

Lot A	0.165 mg.	1.041 mg.
Lot B	0.332 mg.	1.641 mg.

When kelp meal feeding was discontinued, iodine contents decreased rapidly in the white and slowly in the yolk.

2. Where kelp meal was given in double quantity, iodine contents in the white increased to double, whereas in the yolk the increase was not doubled.

3. Iodine in the white seemed to exist in an inorganic form, in the yolk, for the most part, in an organic form.

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Natural Science Report, Ochanomizu University, Vol. 4, No. 1, 1953

Studies on Flavin and Other Substances in *Laminaria japonica*[1)]

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Laminaria japonica is a unique food stuff of a maritime country, Japan, and it has been used traditionally in the diet. It is produced in large quantities as well; nearly equalling the annual production of greens for pickling which ranks as the second highest production item among vegetables in Japan.

The dietary significance of *L. japonica* has heretofore been considered to be chiefly its flavor component, glutamic acid, mannitol, and inorganic components. These substances are present in relatively large quantities in *L. japonica* and there is practically no knowledge regarding any other components.

One of the authors[(1)] quantified the flavin content of various seaweeds using various methods and found that approximately 900γ%, a relatively large amount, is present in *L. japonica*. Flavin is a growth-promoting factor as well as a factor for normalizing dermal function and the growth of hair. In order to investigate the result of its direct effects on a living body, the following animal experiments were carried out.

16 rats were grown for 30-plus days on a flavin-deficient diet and these rats with a marked deficiency were divided into 3 groups for testing: (1) flavin-deficient group, (2) flavin phosphate ester administration group, and (3) powdered *Laminaria* administration group. As a result, the flavin-deficient group showed poor growth, roughening of the fur, and some finally died. On the contrary, both the flavin group and *Laminaria* group showed normal growth and smooth fur. Furthermore, the *Laminaria* group generally responded better than the flavin group in growth, fur length, density, and luster. Because of these results, it seems that *Laminaria* contains other effective substances besides flavin. However, further detailed tests are necessary on this subject. In this paper, a report is made only on the fact that at least the flavin in *Laminaria* particularly improved animal growth and appearance of the fur.

Experiment

(I) Test animals

3 sets of litters totaling 16 rats, provided by Food Research Institute, were grown on a balanced diet until they weighed approximately 50 gr. and were used for tests.

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1) Contribution from Department of Food & Nutrition, Faculty of Home Economics, Ochanomizu University, No. 4.

(II) Feed

(i) Preparation of basic feed

Flavin was removed as much as possible from the starch and casein used for basic feed by the following methods.

(a) Purification of starch

3-fold volumes of distilled water was added to starch and allowed to stand for 10 hours. The mixture was then mechanically stirred for 10 hours. The flavin content of unpurified starch was 23.5γ% while the purified starch contained no flavin at all.

(b) Purification of casein

The flavin content of unpurified casein is 235γ%. It is very difficult to completely remove flavin from casein. After comparative studies of various methods, casein with a minimum flavin content of 62.5γ% was obtained by the following method. Namely, 40- or 80-mesh casein powder mixed with 3 parts of anhydrous methanol was heated while mechanically stirring over a water bath for a total of 16 hours with fresh changes of methanol every 4 hours. (When the mixture was not mechanically stirred, the flavin content remained at 78.0γ%. There was no difference in results between 40- and 80-mesh powder).

(Note) The flavin in (a) and (b) was quantified by the Lumiflavin method after diastase digestion.

The mixing ratio for the basic feed was as follows:

Starch	6.7
Casein	1.8
Soy bean oil (1/11 part liver oil mixed in)	1.1
Salt (V.S.P. No. 2)	0.4

These were mixed with water and cooked well to make a thick cream and fed at the rate of 50-80 gr. per day.

(ii) Vitamin administration

Various vitamin supplements were prepared in aqueous solutions at the following concentrations, placed in separate dropping bottles and 1 drop per rat was squirted directly into the mouth using a dropper.

Table 1.

Vitamin	mg./1 cc	γ/1 drop
Thiamine	1.28	40
Pyridoxine	1.36	40
Ca-Pantothenate	157.5	150
Flavin phosphate (only flavin group)	0.19 (as flavin)	5

(iii) Laminaria administration

The Laminaria used was fresh L. japonica collected this summer at Muroran, Hokkaido, dried at about 100°C and powdered to 40 mesh. 1 gr. of the powder per rat (flavin content, 8γ) was soaked in a small amount of warm water for 30 min. to which a part of the basic feed (about 20 gr.) was added, mixed well and administered in a separate container from the basic feed. Animals in all cases first finished the Laminaria-mixed food and then ate the basic feed. Thus, all the Laminaria offered was eaten.

(III) Growth test

The rats were raised by giving the above basic feed and thiamine, pyridoxine and Ca-pantothenate as shown in Table 1 for about 30 days (few days individual difference existed). They exhibited a marked flavin-deficiency of roughened fur and poor weight gain. Next, the rats were divided into 3 groups by litter and raised for 33 days under the following respective conditions:

(1) Flavin-deficient diet was continued.
(2) Flavin phosphate was administered.
(3) Powdered Laminaria was administered.

(IV) Experimental results

(i) Weight gain curves

A comparison of the rats by litter groups indicated, as shown in Figs. 1, 2, and 3, that the Laminaria group and the flavin group showed rapidly improved growth in all cases, unlike the flavin-deficient group, after the Laminaria or flavin diet was begun.

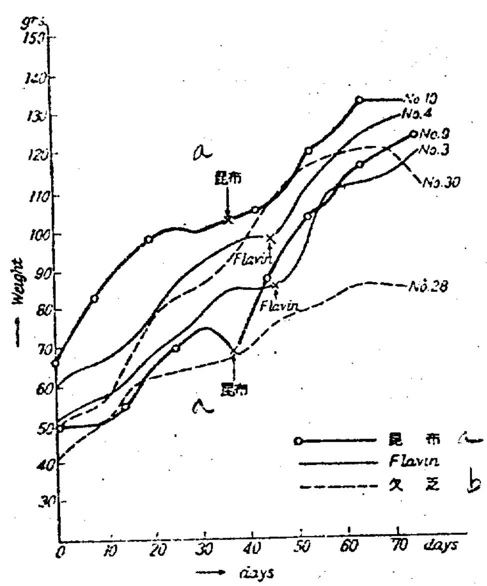

Fig. 1.

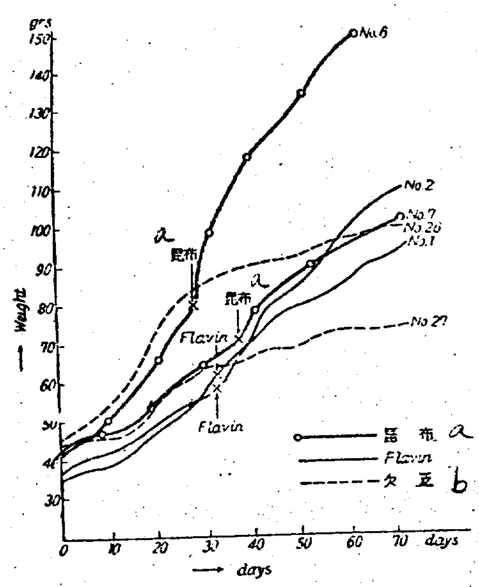

Fig. 2.

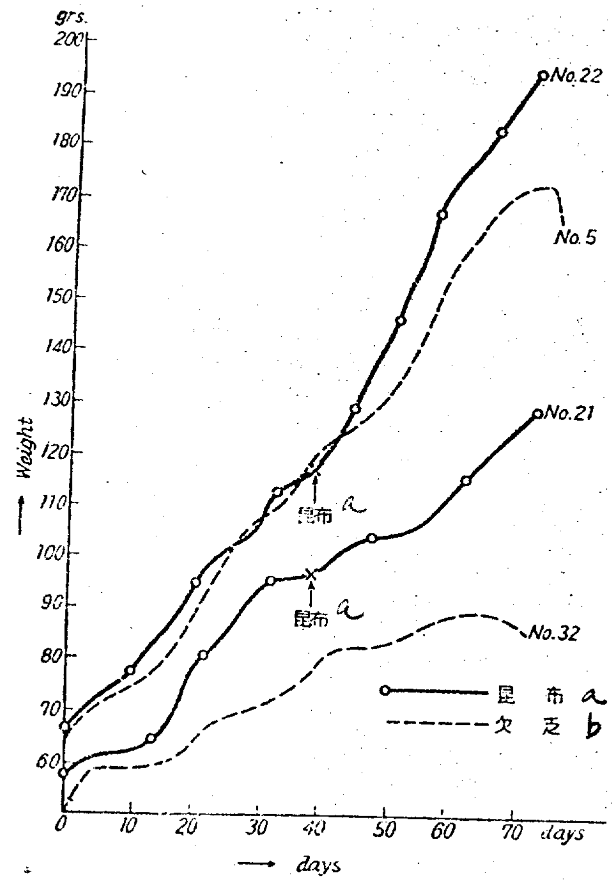

Fig. 3.

Notations for Figs. 1 - 3:

a: Laminaria diet
b: Flavin-deficient diet

(ii) Conditions of the animals

Table 2

			Condition during the several days prior to flavin or *Laminaria* administration	Condition during the several days before and after the completion of tests
Litter A	Flavin-deficient group	No. 26	Coat and growth were normal.	Weight gain was slight, and coat was slightly rough.
		No. 27	Back coat exhibited wet appearance and was lumpy and dishevelled. Bald spot appeared in the center.	Fur thinned, color of eyeballs faded, limbs hemorrhaged, and the rat finally died.
	Flavin adm'd group	No. 1	Back coat roughened, feet turned purple as in cyanosis.	Growth and coat were normal.
		No. 2	Coat was rough and thin.	Growth and coat were normal.
	Laminaria adm'd group	No. 6	A large bold spot appeared in center back.	The bold spot disappeared, coat became long and lustrous, and the rat showed a marked weight gain.
		No. 7	Fur became lumpy and dishevelled.	Growth and coat were normal.
Litter B	Flavin-deficient group	No. 28	Coat was normal, but weight gain was poor.	No weight gain occurred and the fur was thin and rough.
		No. 30	Coat and weight gain were normal.	Little weight gain occurred after about 60 days on test diet. Sudden weight loss occurred on the 73rd day and the rat died.
	Flavin adm'd group	No. 3	Coat was normal. Almost no weight gain occurred.	Growth and coat were normal.
		No. 4	Coat was normal. A trend toward poor weight gain appeared.	Growth and coat were normal.

Litter B	Laminaria adm'd group	No. 9	Fur was dishevelled.	Growth and coat were normal.
		No. 10	Coat was normal, but no weight gain occurred.	Growth was excellent and coat was also beautiful.
Litter C	Flavin-deficient group	No. 5	Growth and coat were excellent.	Both growth and coat were normal (The rat seemed to have some idiosyncrasy). However, beginning from the 72nd day, loss of weight occurred suddenly during the next 4 days.
		No. 32	Growth and coat were normal.	Growth was poor, and the fur was slightly dirty.
	Laminaria adm'd group	No. 21	Fur dishevelled, and no change in weight occurred for 7 days.	Growth and coat were normal.
		No. 22	Although the fur was dishevelled, growth was normal.	Growth was extremely good and the fur was also fluffy, dense, and lusterous.

Comparative photographs showing the most marked differences among the above groups are shown in Figs. 4, 5, and 6.

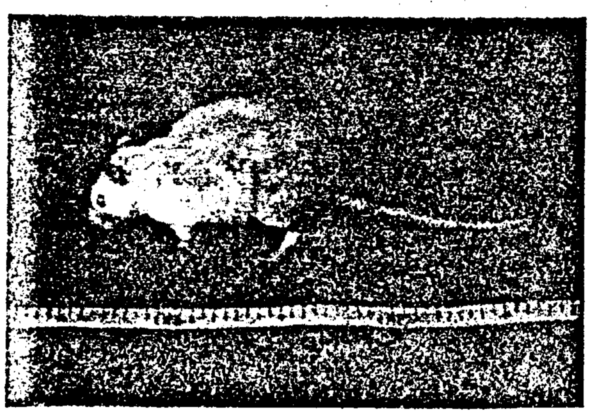

Fig. 4 No. 28 (Flavin-deficient rat)

Fig. 5 No. 3 (Flavin adm'd rat)

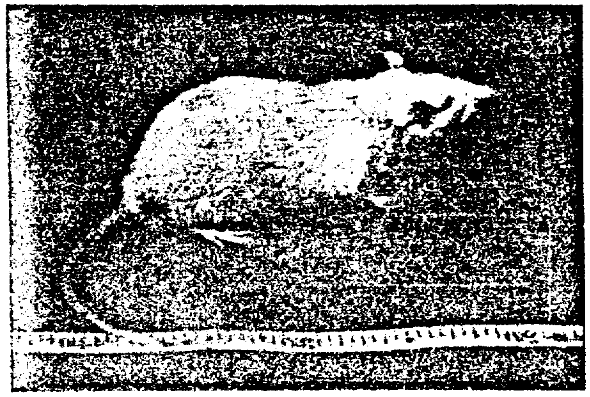

Fig. 5 No. 10 (Laminaria adm'd rat)

Lastly, our deep gratitude is expressed to Dr. Yoshiteru Nakamura of Hokkaido University, Marine Algae Laboratory who supplied us with *Laminaria japonica* for this study, and to Dr. Yoshihito Sakurai of the Food Research Institute who provided us with the experimental animals.

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